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ABSTRACT

Designed to assist science educators in improving preservice/inservice teacher education, this yearbook contains resources and ideas addressing the application of recent research into a format suitable for practitioners. The eight chapters comprising the document deal with: the history and philosophy of science; the psychosocial environment of the classroom; how teachers think; preparation of elementary teachers; preservice secondary science teachers; continuing education for science teachers; the image of science teachers; and the myth of scientific thinking. (CW)

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1987 AETS Yearbook

IMPROVING PRESERVICE/INSERVICE SCIENCE TEACHER EDUCATION: FUTURE PERSPECTIVES

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Foreword

The SMEAC Information Reference Center is pleased to continue cooperating with the Association for the Education of Teachers in Science in producing these Yearbooks.

We invite your comments and suggestions on this series.

Stanley L. Helgeson
Patricia E. Blosser

SMEAC Information Reference Center

Preface

This decade is indeed a time of unrest in science teacher education and has been characterized educationally as a nation at risk. Indicators of risk, such as the low level of scientific and technological literacy among Americans, have been well documented. Science teacher education programs are especially vulnerable to this criticism. This yearbook responds to such criticism and reflects a proactive stance in improving the status of science teacher education.

The authors generate a collage of thinking about the problems and issues which confront science teacher education and provide reasonable suggestions and solutions to complex issues facing our discipline. Enhancing science teacher education through the inclusion of history and philosophy of science, through research on classroom psychosocial environment, or through dialogue with teachers about relevant research may form the fabric upon which exemplary programs are designed.

Models of innovative programs for elementary and secondary teachers of science and for the continuing education of science teachers may provide the impetus for others to modify, adapt, and develop new programs for the 1990's and beyond.

This yearbook culminates in chapters that will encourage philosophical dialogue within and concerning our discipline. The editor and authors sincerely hope that you find these readings informative, stimulating and provocative.

James P. Barufaldi

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CHAPTER 1

Improving Science Teacher Education Programs Through Inclusion of History and Philosophy of Science

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The adoption of the view of teachers as decision makers has significant implications for teacher education programs. Such a characterization of teachers recognizes the diverse educational environment in which teachers must function and the established position (Connelly & Ben Peretz, 1981) that teachers, by necessity, adapt and modify curriculum and instruction models to cope with complex learning environments. Alterations to instructional tasks or activities are made by teachers to meet their needs or to meet the needs of the students as perceived by the teacher. Whether or not teachers should engage in decision making about curriculum design and curriculum implementation is not a debatable issue. Teachers do make decisions in the day to day effort to educate children and will continue to make decisions in spite of attempts by administrators of schools and state legislative bodies to "teacher proof curriculums" through the enforcement of strict curriculum guidelines and teaching models. Thus, the problem for teacher education programs focuses on the need to design preservice and inservice teacher education curriculum which includes decision making as a major goal of teacher education programs.

A variety of opinions and positions about the training of teachers has been articulated by various taskforces, commissions, and boards (Boyer, 1983; National Commission on Excellence in Education, 1983; National Science Foundation, 1980; National Academies of Sciences and Engineering, 1982). One report in particular, "Report of a Panel on the Preparation of Beginning Teachers" (Boyer, 1984) commissioned by the State of New Jersey and chaired by Ernest Boyer, has adopted the position of teachers as decision makers and suggests three areas of knowledge and skill that are essential for beginning teachers. Slot areas are: 1) knowledge of curriculum, which addresses knowledge of what to teach and how it is assessed; 2) knowledge of students, which addresses knowledge of characteristics of students as individuals and of how individuals learn; and 3) knowledge of setting, which deals with knowledge of the dynamics that make up the workplace and tasks of teaching. Each of these three domains of knowledge represents factors which impact on the pedagogical decisions teachers make.

Knowledge of curriculum encompasses both what to teach and how to evaluate what is taught. More specifically, it is the selection and the sequencing of instructional tasks for the purpose of meeting curriculum objectives. While admitting that curriculum objectives are typically decided without the involvement of teachers on a case by case basis, it is nonetheless the individual classroom teacher who determines what specifically is to be emphasized and learned, how it is to be taught and presented to the class, and for what students will ultimately be held responsible. Therefore, knowledge of curriculum is principally concerned with teachers' decisions about what to teach.

On the other hand, knowledge of students and knowledge of setting primarily address decisions teachers will face concerning how to teach. Decisions about grouping, using motivational strategies, when to use teacher aid resources, among others, are representative of topics which emerge from a teacher's understanding of students and of the instructional setting.

The focus of the chapter will be on only the first of the three essential knowledge areas identified by the New Jersey Panel, namely curriculum. More specifically, the chapter will concern itself with knowledge of curriculum on the part of science teachers. Inasmuch as science is a knowledge seeking and knowledge acquiring enterprise in which existing knowledge (the products of science) affects the procedures used to obtain new knowledge (the processes of science), the argument will be made that knowledge of curriculum or knowledge of the subject matter is clearly the most important area of preparation for future science teachers.

Traditionally, a science teacher's preparation in knowledge of subject matter has been the responsibility of various academic departments of science. The science courses which comprise the content preparation an individual is required to complete do not typically address the structure or nature of the knowledge being taught. That is, there is little attention given by introductory courses to the critical analysis of the justification of knowledge claims or the discovery of knowledge claims which comprise the disciplines. Given requests to adapt science education (Bybee, Carlson, and McCormack, 1984) so it begins to focus on science, technology, and society, such deficiencies in science teachers' content preparations are significant. Furthermore, research reports from scholars in the history and philosophy of science are making lucid the need for science teacher education programs to begin considering the inclusion of topics which analyze and evaluate the scientific enterprise and the reasoning employed by science (Martin, 1972; Brush, 1974; Ennis, 1976; Norris, 1984; Duschl, 1985).

Hence, the position will be taken that the preparation of science teachers' knowledge of curriculum will be improved through the inclusion of topics in the history and philosophy of science into science teacher preservice and inservice education programs. The sections to follow will address, in turn, (1) an overview of research on teacher decision making, (2) a discussion of the goals of science education, and, (3) the development of the position that inclusion of the history and philosophy of science in science teacher education programs will better prepare individuals who are capable of making decisions about science curricula which preserve the essential characteristics of the nature of science and scientific inquiry.

TEACHER DECISION MAKING

The process of teaching involves the transmission of knowledge from teachers to learner. In such a process, research on teaching (Peterson & Walberg, 1979) indicates a series of actions must be taken and decisions about such actions must be made concerning how the knowledge to be learned is taught.

Research on teachers' decision making may be classified into two broad groups; preactive and interactive decision making (Shavelson & Stern, 1981). Preactive teacher decisions are concerned with strategies teachers employ and the factors that influence decisions which take place outside of an actual instructional setting. Examples of activities teachers engage in during the preactive stage of decision making are instructional task selection and sequencing, determination of resources and materials to be used during instruction, and allocation of time to student activities. Interactive decision making, on the other hand, addresses decisions teachers make while actively interacting with students. Examples of interactive decision making include compensation, strategic leniency, power sharing, progressive checking, and suppressing emotions (Marland, 1977). This chapter will focus only on preactive decision making and its relationship to teacher planning of instructional tasks.

Research on teacher planning (Yinger, 1977; Clark and Yinger, 1979) has found that teacher planning begins with content. What guides teachers' decision making about the application of the content to the lesson, though, has less to do with the structure of the subject matter and more to do with how the content builds instructional tasks (Shavelson & Stern, 1981). Studies at the elementary school level which examined teacher planning found that teachers consider the instructional task over everything else (Yinger, 1977). Activities were found to be the basic structural unit of planning and action in the classroom. Yinger identified seven features of activities as important considerations in planning decisions. They are location, structure and sequence, duration, participants student behavior, instructional moves or routines, and content and materials.

The implication of this research on teacher planning is that teachers control the selection, development (which is meant to include modifying and adapting), and implementation of instructional tasks. Research on teachers' decisions which affect instructional moves, planning, selection of instructional materials, and recognition of effective teaching characteristics has found that teacher beliefs, perceptions, and judgments influence the decisions which are made (Shavelson, Cadwell, & Izu, 1977; Yinger, 1977; Tversky & Kahneman, 1974; and Clark, Wildfong, and Yinger, 1978). The basic premise of the research is that teachers use a variety of heuristics or strategies to overcome innate limitations in the processing of information. Whether it is through the use of one heuristic, a set of attributions, or other strategies, teachers focus on only certain pieces of information to base their decisions. Although the planning process may begin with considerations for content, research on teacher judgments suggests that content considerations are not the principal factors used by teachers in the selection of activities.

Clark et al. (1978) found that the selection of activities was dependent, in order of importance to teachers, on:

1. whether student motivation and involvement would be stimulated;

2. whether the difficulty of the activity would be low; and

3. whether the purpose of the activity and process of teaching were considered to be good ways to teach.

The absence of considerations for the structure of the subject matter or for the portrayal of the subject matter is not surprising when the context of the research being.cited is considered. Research on teacher decision making has almost exclusively focused on elementary level teachers. Thus, the considerations teachers are making are for a multitude of teacher tasks and, more importantly, for a plethora of instructional topics.

The generalizability of research findings on teacher decision making from elementary trained teachers to teachers trained to teach specific content courses often lacks tenability. The dynamics of teaching at the elementary level are quite distinct from the dynamics of teaching at the secondary level. If one had to select a single distinction which differentiated elementary from secondary level teaching, content or subject matter preparation would have to be a strong candidate for such a distinction. Given the intense focus secondary level teachers have on a single discipline, and the even greater intensity science teachers have on a particular domain of teaching (see Note), the possibility that secondary teachers of science are not using the structures of the subject matter to base decisions on the selection and sequencing of instructional tasks is, in a word, disturbing.

A research study which explored the degree to which science teachers consider the nature of the subject matter in the selection and sequencing of instructional tasks found that science teachers' decisions about instructional tasks are driven by concerns for: (1) enhancing student development, (2) meeting curriculum guide objectives, and (3) coping with pressures of accountability (Duschl, 1983). Such concerns certainly have merit. But limitations were found with the depth of the cognitive and affective levels of student development and to curriculum objectives as judged from the actual instructional tasks taking place in the classroom. Little, if any, consideration was given to the nature of the subject matter from which the instructional tasks ultimately derive their significance.

Recent explications of the desired goals of science education (Harms & Yager, 1982) have included the need to maintain the philosophy of teaching science as inquiry (Welch et al., 1984). In order to teach science as inquiry in secondary level science program, teachers who attempt to teach science as inquiry must have both knowledge of content and knowledge of how that content was generated in scientific investigation (Connelley, Rinehold, Clipsham, Wahlstrom, 1977; p. 42.) The concern is that science teachers are making decisions about what to teach without adequate knowledge of how the subject matter has been developed. A closer examination of the goals of science education is warranted to show why it is essential that teachers of science have knowledge about both the products of science (i.e., facts, theories, beliefs, concepts, etc.) and the developmental processes used to generate the products.

GOALS OF SCIENCE EDUCATION

It is quite feasible to ask that the goals of science education provide for students the same outcome that the goals of science provide for scientists--understanding of natural phenomena for the purpose of being able to make informed decisions about complex technological and scientific issues. The distinction between the goals of science education and science is not one of kinds, rather it is one of degrees. Certainly, all students who enroll in science courses will not become practicing scientists. But increasingly in our science and technology dependent society, individuals are finding that the jobs they hold and the issues which confront them are rooted to basic concepts or processes of science. The dilemma which faces our society is the gap which is developing between scientists' conceptualizaton of science's concepts or processes, and the average citizen's conceptualization of the same concepts and processes. Hence, the dilemma which faces our colleges of education is how to design instruction and to prepare teachers to deliver instruction which can bridge this chasm.

The design of instruction and the preparation of teachers should be consistent with the goals set for science education. With respect to science education in precollege settings, it is generally agreed that instruction should not focus on merely the preparation of future scientists:

> Science teachers tend to be tied to biology, chemistry, physics or Earth science and see their primary goal as one of passing on the substance of such disciplines to as many students as possible (Yager, 1984; p. 52).

> The content of high school courses in physics, chemistry, and biology, essentially the products of the curricular reforms of the early sixties, offer science as seen by the pure scientists. ...These courses neglect the need and interests of the vast majority of students--the 90.4 percent who will not enter college and major in a science, math, or engineering field; (Aldridge & Johnson, 1984; p. 39).

Nor should precollege science instruction be a duplication of what students will have in college courses (Aldridge & Johnson, 1984).

If not science for scientists, then what should be the focus of precollege science education? Wagner (1983) presents a position that the principal objective of science education should be to develop students capable of critical analysis. He identifies as prerequisites for conducting critical analysis in science, grounding in the language of science and in the research paradigms used in science. Connelly et al. (1977) adopt a similar stance when they argue that the goal of science education should be to develop in students the ability to evaluate the status of knowledge claims used in science. They establish four goals for students in science courses:

1. to develop an understanding of the most important content;

2. to develop an understanding of the parts of a pattern of enquiry;

3. to develop the reading skills and habits of mind so as to be able to identify and understand knowledge claims;

4. to develop the evaluative skills and habits of mind so as to be able to assess the status of knowledge claims (Connelly et al., 1977, p. 18).

The first goal can be interpreted as similar to Wagner's appeal for language of science. Both reflect the need to have a content background. The next three goals represent enquiry skills and articulate more clearly Wagner's requirements of research paradigms. More specifically, goals 2, 3 and 4 above represent, respectively, enquiry as it relates to the identification, interpretation, and evaluation of scientific knowledge.

Accepting such goals for the design of secondary level science instruction presupposes a great deal about schools, teachers, and students. It presupposes that schools will have the resources to teach science as inquiry, a costly decision since the textbook alone cannot be the sole source of information, and have an administration which realizes that the delivery of inquiry lessons necessitates specialized instructional settings (e.g., acceptable class sizes) and instructional tasks (e.g., hands-on activities). The demands on students are that they will have the necessary basic skills and decorum for the teacher to teach science as enquiry. Such demands on students recognizes the integration across grade levels and across subject areas that are needed to develop critical thinkers.

But the teacher is the key to the successful implementation of any program in education. Given unlimited resources and administrative support and given students who can read at grade level, write, compute, and conduct themselves properly in the classroom, it is nonetheless the teacher who will be the principal factor in determining how successful students are in learning (DeRose, Lockard, & Paldy, 1979) and in determining the psychosocial environment in which learning occurs (Anderson, 1970; Walberg, 1979).

The dilemma which confronts any teacher who strives for the goals of science instruction outlined above, is how to reduce volumes of scientific knowledge for effective instruction in a restricted amount of time while preserving effective instructional strategies and learning environments. The solution to this problem will reside squarely on the ability of teachers to make decisions about the selection, design, and implementation of instructional tasks which enhance, rather than detract from, children's ability to critically analyze the status of scientific knowledge claims. In addition to maintaining the effectiveness of the learning environment and the instructional strategies employed in the class, it is essential that the characteristics of the nature of scientific inquiry also be maintained. Thus, knowledge of how scientific knowledge has been acquired is as important as knowledge of the scientific content in the preparation of science teachers.

Therefore, the problem which confronts science teacher education programs is how to design a curriculum which educates science teachers to be effective decision makers in the planning and implementation of instructional tasks. More specifically, the problem is how to prepare teachers who are capable of determining the most important content for a topic of investigation while maintaining the integrity of the scientific enterprise and while teaching students about the identification, interpretation, and evaluation of the knowledge claims made by the scientific enterprise.

The bases of the goals of science education set forth above are consistent with the central purpose of education in the United States - the development of the ability to think (Educational Policies Commission, 1961). The EPC stated the ability to think is determined by the development of a set of rational powers; the processes of recalling, imagining, classifying, generalizing, comparing, inferring, deducing, analyzing, evaluating, and synthesizing. Several research reports have indicated that educators are not evenly distributing time in the classroom (Tisher, 1971) or items on tests (Morgenstern & Renner, 1984) to the available array of rational powers. On the contrary, emphasis is being placed almost entirely on the recall of information:

> A miniscule opportunity is available on a few tests for students to demonstrate they can use the rational powers of classifying, generalizing, inferring, deducing, evaluating, and synthesizing. No opportunity was available for students on any tests to demonstrate they have facility with imagining, comparing, and analyzing (Morgenstern & Renner, 1984; p 647.)

It is difficult to argue the position that science education should facilitate the growth of rational powers in students. That science education classes at the pre-college level are dominated by recall memory tasks begs the question why such a situation continues to persist given the fact that the need to focus on rational powers was articulated over twenty years ago.

An answer to such a question must certainly appeal to a variety of factors, social, economical, and epistemological, among others. That issue is the same basic concern raised by Herbert Spencer in the 19th century, what knowledge is most worth knowing? Fortunately, for science educators at least, the natural sciences have a historical development and a set of epistemological structures which can assist curriculum designers and curriculum implementers in making decisions about what should be taught. The "enemy" in the classroom is time. There is only so much time teachers can allocate to the study of a specific scientific field or domain. The first goal by Connelly et al. (1977)--deciding on what is the most important content--is a crucial step for the creation of more time, time which can be used to address the above memory levels of cognition.

PHILOSOPHICAL AND HISTORICAL ANALYSIS OF SCIENTIFIC INQUIRY

The academic training of science teachers is divided unevenly between core courses, science courses, and education and science education courses. What is missing in the majority of science teacher preparation programs are courses or topics in courses which take as an object of analysis the content of the subject matter which wil be used by the future science teacher. The emphasis is presently on content and process skill acquisition, pedagogical style, classroom management, and instructional planning. Each of the areas is important in the development of a teacher. But without a facilitation with the structure and nature of science, the aforementioned areas of training represent a set of insufficient conditions for the preparation of science teachers.

In addition to the goal of using science education classes to increase the rational thinking powers of students, science education organizations (i.e., National Science Teachers Association) have begun to articulate the viewpoint that the preferred context in which science should be taught is with the science-technology-society theme (Bybee, Carlson, and McCormack; 1984). Such a stance by science education researchers and educators only serves to reinforce the claim made in the previous paragraph that teachers of science need to have academic preparation in the issues and skills necessary to analyze the relationships the structure and nature of scientific inquiry have internally in the development of theories and externally with science, technology, and society.

The recognition of the need for science teachers to have preparation in the philosophical, historical, and sociological aspects of science is a position which has been advanced for decades (Rutherford, 1964; Gallagher, 1984; and Duschl, 1985). Similarly, a number of writers have presented arguments about the distinctions which would exist between teachers who hold accurate views of the nature of science and teachers who maintain false views of the nature of science (Robinson, 1969; Martin, 1972; Norris, 1984). The focus of the remainder of the chapter will be to address specific applications about how topics in the history and philosophy of science can be used by science teachers in their preactive decision making to meet the goals of science education outlined above. More specifically, such applications wil assist teachers in the design and sequencing of instructional activities which address the objectives of developing students' rational thinking powers and of introducing students to the symbiotic-type relationship which exists among science, technology, and society.

The sections to follow will discuss, in turn, how argument patterns, structure of scientific theories, and the developmental nature of scientific knowledge can each be used by science teachers to assist them in the planning and implementation of science units and science lessons.

Argument Patterns in Science Education

The use of philosophical analysis to examine educational practice has been described by Roberts and Russell (1975) as an alternative approach to science education research. More specifically, Russell (1983) did research on how Toulmin's (1958) argument patterns could be used by teachers during inquiry discussions to increase their own propensities to use and to demand from students warrants or reasons concerning how a given conclusion relates to a specific set of data. Russell concluded that teachers who use warrants in their argument patterns rather than their position as 'the teacher' present themselves as rational authority figures to students. Teachers who rely on their position as a teacher present themselves as irrational authority figures. Another argument pattern which has been identified as potentially useful in science education (Martin, 1972) is the Deductive-Nomological Model of Explanation developed by Hempel and Oppenheim (1948) and further refined by Hempel (1965). The model is based on the premise that scientific explanations can be logically deduced from causal laws of science if a set of antecedent conditions is met.

The merits of such patterns for science classes require teachers, in their planning and lecturing, and students, in their writing and discussing, to identify the premises, to justify the premises, and to speak to the relationships which exist among the premises. An outcome is that students will engage in higher cognitive tasks. Furthermore, such cognitive tasks will be quite similar to the goals of science identified by Connelly and Finegold et. al. (1977), discussed earlier. The use of argument patterns also accomplishes the clarification of "tacit assumptions that must be made in an explanatory activity if its discourse is to be logically and epistemologically adequate" (Martin, 1972; p. 52).

Using argument patterns to plan instruction will also assist teachers in determining what knowledge is most important for students to learn. By treating educational topics as arguments in which a set of premises leads to a statement of conclusion, teachers can make decisions about what knowledge claims are necessary to bring about the conclusion sought. Teachers can also use argument patterns to design questioning patterns in enquiry discussions and post-lab discussions (Connelly and Finegold et al, 1977). Being able to categorize scientific knowledge as either necessary or sufficient conditions in the development of an argument, which has as its conclusion a learning outcome on the part of students, will serve to eliminate items from the curriculum that take up time but contribute little to learning.

Now let us consider a science unit on genetics. If the unit objecitve is to teach students about the role genes have in biological diversity and species evolution, then what knowledge claims are necessary for bringing about the desired result? Knowing about cell division (mitosis) and about sex cell·production (meiosis) are certainly necessary for explaining genetic variation. But one has to stop and wonder about whether identifying pictures of the stages of metosis or being able to solve a variety of Punnett Square problems is necessary for a student's conceptual understanding that genes get mixed through sexual reproduction and altered through mutation processes. Yet being able to solve Punnett Square problems will occupy full weeks of instruction in many high school biology classes. It is claimed that there is a need for teachers, and curriculum writers too, to evaluate the merit of the scientific topics so that the appropriate emphasis is given to the topic. Using argument patterns and conditional statements can assist in such an analysis of scientific content.

Similar positions about the logic of the language used by teachers and the applications it has for educational thought have been posited by Scheffler (1960) and by Smith and Meux (1970). That it has yet to be widely implemented remains an enigma of educational practice since the goal of education is to develop thinking skills. That the use of argument patterns is not a central part of science instruction is also an enigma due to the logical nature in which many, but not all, knowledge claims of science are constructed.

For purposes of clarity, the author of this chapter is not advocating the position that students be taught formal logic although such opinions and programs for children do exist (Instruction for the Advancement of Philosophy of Children, Montclair State College, NJ; Matthew Lipman, Director). Rather the position being taken is that the use of argument patterns in teachers' decision making can be a constructive mechanism for teachers to plan lectures and discussions. If the teacher does not understand the logical connections or the fallacious connections present in scientific discourse, then what hope is there that the learners will acquire similar skills. Furthermore, if teachers cannot judge the merit of the knowledge claims being used by textbooks and curriculum guides (which are often out of date with contemporary scientific knowledge), then again what hope is there that the students will be able to distinguish revolutionary scientific ideas from "crank" scientific ideas?

The Structure of Scientific Theories

The recent debates over the teaching of evolution and scientific creationism have made very clear the misconceptions the general public has about the role theories have in scientific inquiry. The confusion that exists among the general public and among educators seems to exist in their inability to distinguish the strong theories which are pillars of science from the fringe theories which are fledgling ideas in science.

New methods for researching and writing history of science (Thackray, 1980) have provided evidence that the rigid forms of scientific theories characterized by the 'laws of nature' in physics and advocated as the structure of all theories by early 20th century philosophers just do not exist. Rather, what has been revealed is that theories, like everything else in science, progress through stages of development. Similarly, new philosophical views about the nature of scientific inquiry have recognized where previous views have not, the central role theories have in the development and the advancement of scientific understanding (Suppe, 1977).

To equate scientific theories with scientific facts is sheer folly (Science News, 1984).

Within the scientific disciplines, there exist levels of theories and modes of explanation. For discussion purposes theories will be treated as being either central, frontier, or fringe to the domain of scientific enquiry (Dutch, 1982). Four general modes of explanations used in varying degrees by different disciplines of science (Nagel, 1961) will also be discussed. Included are: (1) causal explanations - characteristics of the deterministic theories of physics and chemistry; (2) historical explanations characteristic of concepts developed in geology and anthropology; (3) teleological explanations - characteristic of the function-related explanations used in the biological sciences; and, (4) statistical - probabilistic explanations - characteristic of theories, hypotheses, and concepts based on numbers and which are increasingly becoming a part of all branches of science.

Only through comparative and critical analyses will science teachers come to realize that all knowledge claims in science are not equal. But the inequality does not render such claims unscientific.

The new discoveries in the history of science indicate three things about the nature of science (Shapere, 1984): (1) standards for considering scientific theories and explanations as legitimate can change from one period of time to another; (2) differing sets of criteria used to establish the standards at the different periods could not be ruled more or less rational or correct than any of the other periods; and (3) criteria are intimately linked to the content of the scientific beliefs at that period.

These three discoveries were made during the same time that the National Science Foundation was involved in the development of curriculum projects. The failure to integrate these three discoveries into science teacher education programs has allowed science instruction at the precollege levels to maintain its presuppositionist and empiricist perspectives of science (Finley, 1983; Norris, 1984; Duschl, 1985 in press).

Nagel (1961) distinguishes common sense knowledge from scientific knowledge by claiming scientific knowledge seeks to know why and how such a phenomenon occurs whole common sense knowledge only seeks to know what occurs. The quest for the how and why explanations can be thought of as the goal of scientific inquiry. Such explanations exist as the scientific theories that a community of scientists embrace. In the development sequence of the growth of scientific knowledge, it is theories which provide meaning to facts and not facts which provide meanings to theories.

Consider the evolution of explanations for earthquakes. Over the past 100 years the cause of earthquakes has been attributed to the gravitational pull of the moon, changes in barometric pressure, isostatic rebounding of mountains, movement of continents on crustal plates and gas ascending from the mantle along preexisting fault lines (Duschl, in press). The existence of earthquakes is a fact. But the reason certain regions of the earth are more prone to earthquakes than others is the domain of theoretical science. But, how do new theoretical ideas become accepted?

A useful schema for the ranking of theories is the one devised by Trefil (1978) in which scientific ideas are divided into center, frontier, and fringe domains. Dutch (1982) describes center ideas as those theories which are established firmly among scientific communities; included are relativity, quantum theory, the laws of thermodynamics, Kepler's laws of planetary motion, and Newton's laws of motion. Frontier ideas are theories which are sound but have competition in the form of equally sound alternative ideas. Frontier ideas are also theories in which significant problems remain. Dutch states that plate tectonics and evolution belong on the center-frontier boundary. He considers sociobiology, extraterrestrial intelligence, and sub-quark physics as frontier ideas. Fringe ideas, on the other hand, are theories which are highly speculative or weakly confirmed. Some have scientific basis, i.e., the extinction of dinosaurs by meteor showers, while others are spurious because they are not supported by scientific data. Dutch identifies psychic phenomena, the Loch Ness Monster, Velikovsky's world collision, and scientific creationism as examples of non-scientific fringe ideas.

The ability to distinguish crank ideas from revolutionary ideas is certainly a characteristic of a scientifically literate person. It is apropos, then, to argue that fringe science, contemporary and historical, be an object of investigation by students of science (Radner and Radner, 1982). Trefil's simple design is in some regards quite similar to Lakatos' (1970) description of the growth of scientific knowledge in which scientific theories are either members of the negative heuristic - the "hard core" of a research program - or members of the positive heuristic - the construction of the "protective belt" of a research program.

In each schema, new scientific ideas must progress toward the center of established scientific knowledge. New theories are required in science because old theories are found to be wanting. That is, the ability to explore for new data and new facts due to advances in technology often gives rise to information which cannot be accounted for by existing theories. Such discoveries, when numerous enough, eventually force scientists to develop a new theory to explain the new information as well as the old information.

Each of the major scientific disciplines, life sciences, earth sciences, and physical sciences has experienced dynamic change since the 1800's with respect to the theories each embraces. Relativity and quantum theory in physics and chemistry, plate tectonics in geology, and evolution and molecular biology in the life sciences represent examples of major developments in scientific theories. If prospective science teachers were to investigate the development of the theories which comprise the core of understanding of the disciplines they will teach, then they would be in a better position to accurately present the nature of scientific knowledge and of scientific inquiry.

The intent of having science teachers examine from a historical as well as from a philosophical perspective the development of scientific knowledge through examinations of the development of scientific theories is two fold. First, the development of scientific theories is the goal of scientific investigation which seeks explanations of phenomena (Giere, 1984; Martin, 1972; Suppe, 1977). Teachers of science should be familiar with the developmental nature of the discipline they will teach. Second, it is anticipated that such familiarity will impact on science teachers' preactive decision-making concerning the selection and sequencing of instructional tasks. Figures 1 and 2 are examples of one science teacher's analysis of the historical and conceptual frameworks of the Theory of Plate Tectonics. These frameworks were developed using guidelines for curriculum development outlined by Posner and Rudnitshy (1978).

Beyond the definition of terms and the memorization of facts such concept maps and frameworks assist teachers in understanding the relational importance of the curriculum topics and concepts that make up the science units they will plan and then teach. As stated earlier, all theories in science are not equal, nor are concepts and principles which comprise theories. Studying the development of scientific theories can assist teachers in evaluating the status of the knowledge claims which make up the subjects they will teach.

Knowledge of the development of a scientific theory, of the new technologies which have borne new facts, of how old facts were discarded or assimilated by newer theories, of the critical experiments and the scientists which contributed to the growth of knowledge, and of the social conditions in which new ideas were developed can each assist science educators in making decisions about what should be a part of their lessons and how such topics should be sequenced. Such knowledge on the part of teachers addresses the second requirement Connelly and Finegold et. al. (1977) cite as necessary for teaching science as enquiry, knowledge of how content has been generated in scientific investigations. The importance of such knowledge on the part of teachers of science is captured in a passage from Shapere (1984):

> The question of why science today believes the peculiar things it does about the university, and why it is willing to consider the alternative it does, requires attention to the question of how science has come to think in those ways (p. 190).

Investigating how science has come to think in the ways it does is the domain of history and philosophy of science. The discipline of the history of science is still a first generation discipline in American academic circles (Thackray, 1980). But its impact has already had significant effects on philosophy of science and the training of philosophers of science. History of science offers national studies, discipline studies, science and religion studies, science, medicine, and technology studies, philosophy, psychology, and sociology of science studies, and great man studies (Thackray, 1980).

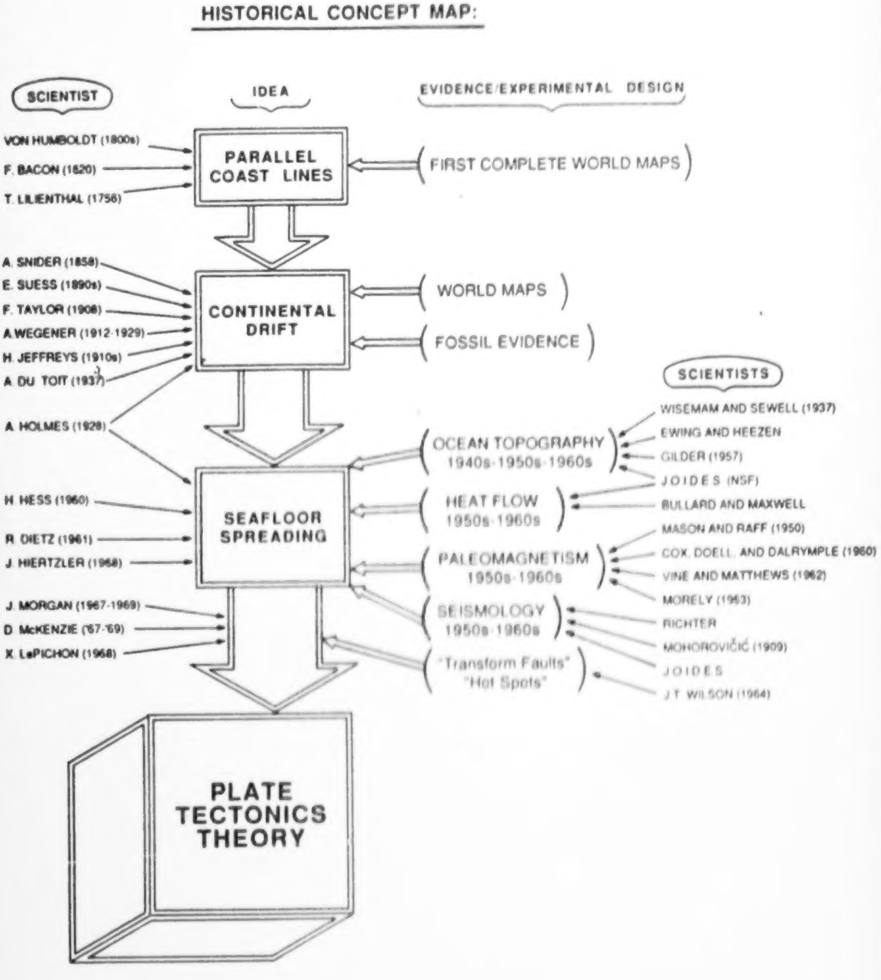
HISTORICAL CONCEPT MAP:
SCIENTIST
IDEA
EVIDENCE/EXPERIMENTAL DESIGN
VON HUMBOLDT (1800s)
F. BACON (1620)
T. LILIENTHAL (1756)
PARALLEL COAST LINES
FIRST COMPLETE WORLD MAPS
A. SNIDER (1858)
E. SUESS (1890s)
F. TAYLOR (1908)
A.WEGENER (1912-1929)
H. JEFFREYS (1910s)
A. DU TOIT (1937)
A. HOLMES (1928)
CONTINENTAL DRIFT
WORLD MAPS
FOSSIL EVIDENCE
SCIENTISTS
WISEMAM AND SEWELL (1937)
EWING AND HEEZEN
GILDER (1957)
JOIDES (NSF)
BULLARD AND MAXWELL
MASON AND RAFF (1950)
COX, DOELL, AND DALRYMPLE (1960)
VINE AND MATTHEWS (1962)
MORELY (1963)
RICHTER
MOHOROVIČIĆ (1909)
JOIDES
J.T. WILSON (1964)
H. HESS (1960)
R. DIETZ (1961)
J. HIERTZLER (1968)
SEAFLOOR SPREADING
OCEAN TOPOGRAPHY 1940s-1950s-1960s
HEAT FLOW 1950s-1960s
PALEOMAGNETISM 1950s-1960s
SEISMOLOGY 1950s-1960s
"Transform Faults" "Hot Spots"
J. MORGAN (1967-1969)
D. McKENZIE ('67-'69)
X. LePICHON (1968)
PLATE TECTONICS THEORY

Figure 1 - Historical concept map. Identifier development of theory.

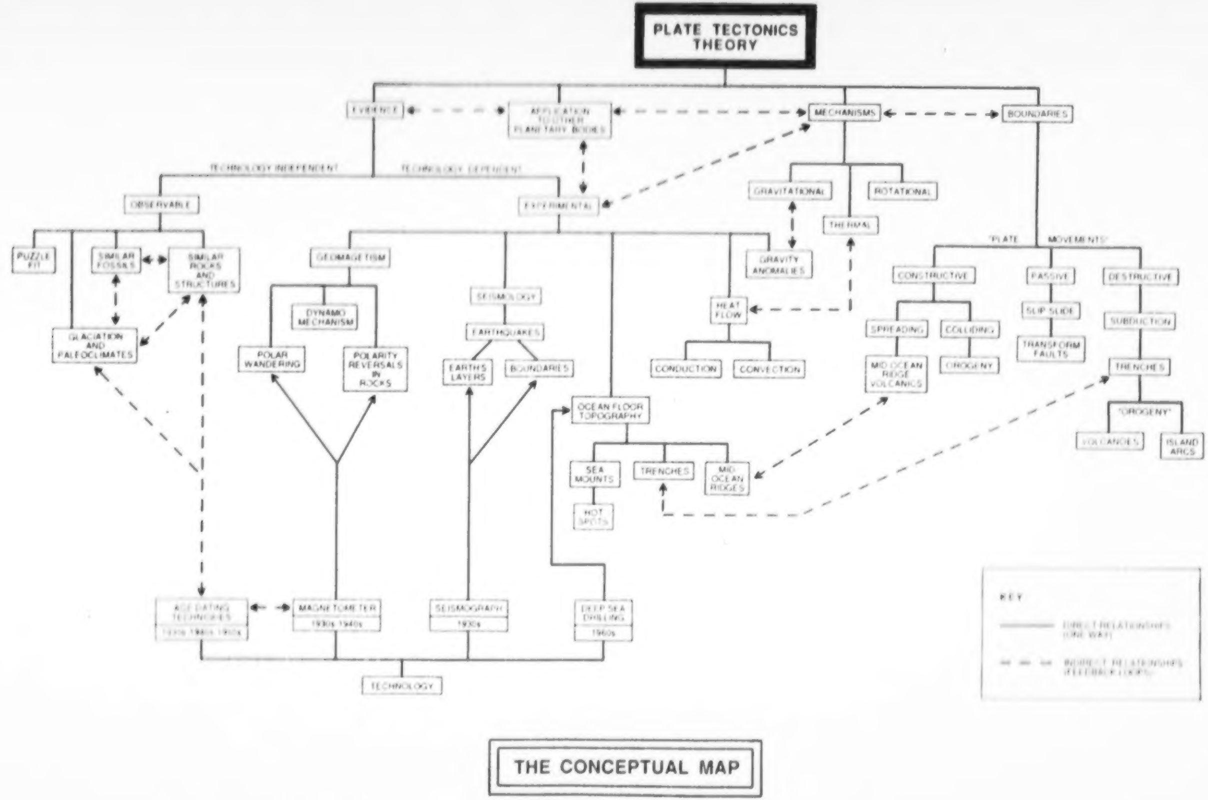
PLATE TECTONICS THEORY
EVIDENCE
APPLICATION TO OTHER PLANETARY BODIES
MECHANISMS
BOUNDARIES
TECHNOLOGY INDEPENDENT
TECHNOLOGY DEPENDENT
OBSERVABLE
EXPERIMENTAL
GRAVITATIONAL
THERMAL
ROTATIONAL
PUZZLE FIT
SIMILAR FOSSILS
SIMILAR ROCKS AND STRUCTURES
GLACIATION AND PALEOCLIMATES
GEOMAGETISM
DYNAMO MECHANISM
POLAR WANDERING
POLARITY REVERSALS IN ROCKS
SEISMOLOGY
EARTHQUAKES
EARTH'S LAYERS
BOUNDARIES
GRAVITY ANOMALIES
HEAT FLOW
CONDUCTION
CONVECTION
OCEAN FLOOR TOPOGRAPHY
SEA MOUNTS
HOT SPOTS
TRENCHES
MID OCEAN RIDGES
"PLATE MOVEMENTS"
CONSTRUCTIVE
PASSIVE
DESTRUCTIVE
SPREADING
COLLIDING
MID OCEAN RIDGE VOLCANICS
OROGENY
SLIP SLIDE
TRANSFORM FAULTS
SUBDUCTION
TRENCHES
"OROGENY"
VOLCANOES
ISLAND ARCS
AGE DATING TECHNIQUES
1930s 1940s 1950s
MAGNETOMETER
1930s 1940s
SEISMOGRAPH
1930s
DEEP SEA DRILLING
1960s
TECHNOLOGY
KEY
DIRECT RELATIONSHIPS (ONE WAY)
INDIRECT RELATIONSHIPS (FEEDBACK LOOPS)
THE CONCEPTUAL MAP

Figure 2. The conceptual map.

The first crisis in science education, 1955, established the context of justification in secondary level science education programs and in science teacher training programs. The context of justification is described as the testing of scientific ideas to establish their merit, i.e., acceptance through verification. It is the approach used in the training of scientists. The time has come, however, with the growth of the discipline of history of science, for science teacher educators and science education researchers to investigate how inclusion of topics which explore the developmental aspects of science, the context of discovery, can aid in the preparation of teachers and science curriculum. Benefits to science curriculum have been explored with mixed results (Russell, 1981; Welch and Walberg, 1972). The history of science approach was used with the National Science Foundation funded program, Harvard Project Physcis (Rutherford, Holton, and Watson, 1970). But, as was pointed out in the introduction of this chapter, teachers adapt and modify instructional tasks in their planning and implementation. What has yet to be clearly investigated and articulated are the benefits that may be incurred by having teachers make decisions about what to teach by appealing to issues which relate to the developmental nature of the discipline they are teaching.

It is hypothesized that considerations for the history and the philosophy of science will assist teachers in developing critical thinking skills among students. It will also help in developing lessons that integrate science with technology and society. Teachers' appeals to the context of discovery in science, the development of scientific theories, will enable them to make decisions about the selection, sequencing, and implementation of instructional tasks that are consistent with the nature of scientific inquiry. In content specific classes teachers' decision making should not be devoid of considerations for the nature of the subject matter they are teaching. The use of argument patterns and conceptual frameworks or theory development are examples of how research in the history and philosophy of science can be used to improve the preparation of science teachers.

Note - Certification requirements for secondary level teachers of science are typically subject matter specific. A person trained in biology receives a biology certificate and, unless emergency conditions prevail, will not be placed in teacher assignments other than biology. However, secondary mathematics, English, or social studies teachers do not share similar divisions of labor. For example a mathematics teacher may be assigned to any or all of the mathematics courses taught without violating certification guidelines.

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CHAPTER 2

Improving Science Teacher Education Programs Through Inclusion of Research on Classroom Psychosocial Environment

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It is understandable that science teachers today often teach as they were taught themselves as students. After all, given that students spend 15,000 hours in classrooms by the end of their secondary schooling (Rutter, Maughan, Mortimore, Ouston & Smith, 1979), the teacher's time as a school student far exceeds his or her period of teacher training. What is needed to break this nexus is new input and new ideas within science teacher education programs, especially those which will help teachers become more reflective and retrospective about the way they are teaching.

Science education research provides one possible source of ideas whose inclusion has the potential of improving science teacher education curricula. Already the NSTA-sponsored What Research Says to the Teacher series in the USA and the Science Teacher Education Project (STEP) in the UK provide some good examples of the relevance and value of particular research concepts and findings for the improvement of science teaching. It is desirable that preservice teachers begin to become acquainted with these ideas through their incorporation into science teacher education programs.

The field of classroom psychosocial environment provides a good illustration of a thriving field of study among science education researchers (see Fraser, 1981b, 1986a; Chavez, 1984; Fraser & Walberg, 1981) which furnishes a number of ideas and techniques which are potentially valuable for improving teaching practice and for inclusion in science teacher education programs. After a brief introduction to the field of classroom environment, this paper aims to demonstrate the usefulness in science teacher education programs of material from the field of classroom environment which (1) sensitizes preservice teachers to subtle but important aspects of classroom life, (2) illustrates the usefulness of classroom environment measures in curriculum evaluation, and (3) illustrates how assessments of classroom environment can be used to facilitate practical improvements in classrooms.

Field of Classroom Environment

Although it is clearly important for educators to consider student academic achievement and other valued educational outcomes, they cannot give science teacher education students a complete picture of the educational process. Classroom environment work provides one approach to investigating what happens to students during their schooling which involves students' perceptions of psychosocial aspects of their classroom learning environments.

In contrast to methods which rely on outside observers, the approach described in this paper defines classroom environment in terms of the shared perceptions of the students and sometimes the teachers in that environment. This has the dual advantage of characterizing the class through the eyes of the actual participants and capturing data which the observer could miss or consider unimportant. For example, students often ignore frequently occurring classroom stimuli and act in the light of how they expect the teacher to behave. Students are at a good vantage point to make judgments about classrooms because they have encountered many different learning environments and have enough time in a class to form accurate impressions. Also, even if teachers are inconsistent in their day-to-day behavior, they usually project a consistent image of the long-standing attributes of classroom environment.

Fraser and Walberg (1981) outline some advantages which student perceptual measures have over observational techniques. First, paper-and-pencil perceptual measures are more economical than classroom observation techniques which involve the expense of trained outside observers. Second, perceptual measures are based on students' experiences over many lessons, while observational data usually are restricted to a very small number of lessons. Third, perceptual measures involve the pooled judgments of all students in a class, whereas observation techniques typically involve only a single observer. Fourth, students' perceptions, because they are the determinants of student behaviour more so than the real situation, can be more important than observed behaviours. Fifth, perceptual measures of classroom environment typically have been found to account for considerably more variance in student learning outcomes than have directly observed variables.

Another approach to studying classroom environments involves application of the techniques of naturalistic inquiry and case study which are well illustrated by the vivid descriptions of classroom settings found in popular books such as To Sir With Love, Up the Down Staircase, Death at an Early Age, and Thirty-Six Children. Some good examples of classroom environment studies following these more qualitative approaches include Jackson (1968), Cusick (1973), Rutter et al. (1979), Case Studies in Science Education (Stake & Easley, 1978), and Gallagher (1984). Cusick, for instance, gathered his descriptions during a six-month period in which he attended a high school daily, associated with students, went to class, had meals in the cafeteria and took part in informal classroom and corridor activities.

The work described here builds upon the seminal independent research programs commenced by Herbert Walberg and Rudolf Moos two decades ago. It was almost 20 years ago when Walberg began developing earlier versions of the widely used Learning Environment Inventory as part of the research and evaluation activities of Harvard Project Physics (see Anderson & Walberg, 1968; Walberg, 1968; Walberg & Anderson, 1968a, b). Two decades ago also marks the time when Moos began developing the first of his world-renowned social climate scales, including those for use in psychiatric hospitals (Moos & Houts, 1968) and correctional institutions (Moos, 1968), which ultimately resulted in development of the widely known Classroom Environment Scale.

The way that the important pioneering work of Walberg and Moos on perceptions of classroom environment developed into major research programs and spawned a lot of other research is reflected in numerous comprehensive literature overviews. These include books (Moos, 1979a; Walberg, 1979), monographs (Fraser, 1981b; Fraser & Fisher, 1983a), a guest-edited journal issue (Fraser, 1980), an annotated bibliography (Moos & Spinrad, 1984), several state-of-the-art literature reviews (Anderson & Walberg, 1974; Randhawa & Fu, 1973; Walberg, 1976; Walberg & Haertel, 1980; Fraser, 1984, 1986b; Chavez, 1984), including special purpose reviews with an emphasis on classroom environment work in science education (Fraser & Walberg, 1981), in Australia (Fraser, 1981a), and in Germany (Dreesman, 1982; Wolf, 1983).

The considerable body of prior classroom environment research which has focused specifically on science classrooms includes studies of the effects of classroom environment on student outcomes (Walberg, 1972; Lawrenz, 1976; Fraser, 1979; Hofstein, Gluzman, Ben-Zvi, & Samuel, 1979); Haladyna, Olsen, & Shaughnessy, 1982; Fraser & Fisher, 1982a, b), the use of classroom environment variables as process criteria in curriculum evaluations (Welch & Walberg, 1972; Fraser, 1979a), the study of differences between students and teachers in their perceptions of actual and preferred classroom environment (Fisher & Fraser, 1983), the investigation of the person-environment fit hypothesis of whether students achieve better in their preferred classroom environment (Fraser & Fisher, 1983b, c), the application of classroom environment assessments in facilitating improvements in classrooms (Fraser & Fisher, 1986), and studies of the way that classroom environment varies with other variables such as teacher sex (Lawrenz & Welch, 1983), class size (Anderson & Walberg, 1972), grade level (Welch, 1979), or grouping of students in the laboratory on the basis of formal reasoning ability (Lawrenz & Munch, 1984).

Sensitization to Subtle, Important Aspects of Classrooms

Through research on classroom environment, there is an opportunity for science educators to familiarize their students with many important but subtle aspects of classroom life. In particular, this familiarization can be achieved by introducing teacher education students to instruments which assess classroom environment and having them administer an instrument in classrooms during teaching practice periods. If organized in appropriate ways, discussion of results obtained via questionnaire administration can provide a very worthwhile stimulus for preservice teachers to reflect seriously about their classrooms and to plan actions which will lead to the improvement of classroom environments.

Table 1 provides the scale name and a scale description for five widely applicable classroom environment instruments. The first three of these - namely, the Learning Environment Inventory (LEI) (Anderson & Walberg, 1974; Fraser, Anderson & Walberg, 1982), the Classroom Environment Scale (CES) (Trickett & Moos, 1973; Moos & Trickett, 1974), and the Individualized Classroom Environment Questionnaire (ICEQ) (Rentoul & Fraser, 1979; Fraser, in press) - are suitable for use at the high school level. The My Class Inventory (MCI) (Fisher & Fraser, 1981; Fraser, Anderson, & Walberg, 1982) is designed for the elementary school level, whereas the college and University Classroom Environment Questionnaire (CUCEI) (Fraser, Treagust, and Dennis, 1986) is intended for use at the higher education level. Although the main application of these instruments in past research has been the measurement of students' perceptions of actual classroom environment, numerous interesting studies also have used these scales to assess preferred classroom environment. The preferred forms are concerned with goals and value orientations and measure the perceptions of the classroom ideally liked or preferred by students.

Table 1. Scale Description for the Individual Dimensions in LEI, CES, ICEQ, MCI, and CUCEI

Scale	Scale Description
Learning Environment Inventory (LEI) (Secondary school level)	
Cohesiveness	Extent to which students know, help and are friendly towards each other
Diversity	Extent to which differences in students' interests exist and are provided for
Formality	Extent to which behavior within the class is guided by formal rules
Speed	Extent to which class work is covered quickly
Material Environment	Availability of adequate books, equipment, space and lighting
Friction	Amount of tension and quarrelling among students
Goal Direction	Degree of goal clarity in the class
Favoritism	Extent to which the teacher treats certain students more favourably than others
Difficulty	Extent to which students find difficulty with the work of the class
Apathy	Extent to which the class feels no affinity with the class activities
Democracy	Extent to which students share equally in decision-making related to the class
Cliqueness	Extent to which students refuse to mix with the rest of the class
Satisfaction	Extent of enjoyment of class work
Disorganization	Extent to which classroom activities are confusing and poorly organized
Competitiveness	Emphasis on students competing with each other

Table 1 (continued)

Classroom Environment Scale (CES) (Secondary school level)	
Involvement	Extent to which students have attentive interest, participate in discussions, do additional work and enjoy the class
Affiliation	Extent to which students help each other, get to know each other easily and enjoy working together
Teacher Support	Extent to which the teacher helps, befriends, trusts and is interested in students
Task Orientation	Extent to which it is important to complete activities planned and to stay on the subject matter
Competition	Emphasis placed on students competing with each other for grades and recognition
Order & Organization	Emphasis on students behaving in an orderly, quiet and polite manner, and on the overall organization of classroom activities
Rule Clarity	Emphasis on clear rules, on students knowing the consequences for breaking rules, and on the teacher dealing consistently with students who break rules
Teacher Control	The number of rules, how strictly rules are enforced, and how severely rule infractions are punished
Innovation	Extent to which the teacher plans new, unusual and varying activities and techniques, and encourages students to contribute to classroom planning and to think creatively

Individualized Classroom Environment Questionnaire (ICEQ) (Secondary school level)	
Personalization	Emphasis on opportunities for individual students to interact with the teacher and on concern for the personal welfare and social growth of the individual
Participation	Extent to which students are encouraged to participate rather than be passive listeners
Independence	Extent to which students are allowed to make decisions and have control over their own learning and behaviour

Table 1 (continued)

Investigation	Emphasis on the skills and processes of inquiry and their use in problem-solving and investigation
Differentiation	Emphasis on the selective treatment of students on the basis of ability, learning style, interests and rate of working
My Class Inventory (MCI) (Primary school level)	
Cohesiveness	Extent to which students know, help and are friendly towards each other
Friction	Amount of tension and quarrelling among students
Difficulty	Extent to which students find difficulty with the work of the class
Satisfaction	Extent of enjoyment of class work
Competitiveness	Emphasis on students competing with each other
College and University Classroom Environment Inventory (CUCEI) (Tertiary level)	
Personalization	Emphasis on opportunities for individual students to interact with the instructor and on concern for students' personal welfare
Involvement	Extent to which students participate actively and attentively in class discussions and activities
Student Cohesiveness	Extent to which students know, help and are friendly towards each other
Satisfaction	Extent of enjoyment of classes
Task Orientation	Extent to which class activities are clear and well organized
Innovation	Extent to which the instructor plans new, unusual class activities, teaching techniques and assignments
Individualization	Extent to which students are allowed to make decisions and are treated differentially according to ability, interest and rate of working

The initial development and validation of a preliminary version of the LEI began in the late 1960s in conjunction with the evaluation and research on Harvard Project Physics. Initially, Walberg (1968) devised an instrument called the Classroom Climate Questionnaire, which included 18 scales selected by factor analysis and considered meaningful for the description of school class groups. The LEI is an expansion and improvement of the Classroom Climate Questionnaire. A form of the LEI developed in 1968 contained 14 scales, but a 1969 revision was expanded to include 15 scales. In selecting the 15 climate dimensions, an attempt was made to include as scales only concepts similar to those found useful in theory and research in education and concepts which intuitively appeared relevant to classrooms. The final version of the LEI contains a total of 105 statements (i.e., seven per scale) descriptive of typical school classes. The respondent expresses degree of agreement or disagreement with each statement on a four-point scale with response alternatives of Strongly Disagree, Disagree, Agree, and Strongly Agree. Typical items contained in the LEI are "All students know each other very well" (Cohesiveness), "Certain students in the class are responsible for petty quarrels" (Friction), "Students do not have to hurry to finish their work" (Speed), and "The class is well organized and efficient" (Disorganization). The scoring direction (or polarity) is reversed for some items. Also, in the most recent published version of the LEI (Fraser, Anderson, & Walberg, 1982), the response format is arranged in such a way as to allow ready hand scoring.

The CES is one of a set of nine separate, but somewhat similar instruments, called the Social Climate Scales (Moos, 1974b) which were developed to assess a variety of human environments including hospital wards, university residences, correctional institutions, military companies, families, and work settings. The original version of the CES consisted of 242 items representing 13 conceptual dimensions (Trickett & Moos, 1973). Following trials of the items in 22 classrooms and subsequent item analysis, the number of items was reduced to 208. This item pool was administered in 45 classrooms and modified to form the final version. These items were evaluated statistically according to whether they discriminated significantly between the perceptions of students in different classrooms and whether they correlated highly with their scale scores. The final version of the CES contains nine scales with 10 items of True-False response format in each scale. This version is available in published form which includes a separate answer sheet and a transparent hand scoring key (Moos & Trickett, 1974). Typical items in the CES are "This class is more a social hour than a place to learn something" (Task Orientation), "Students don't always have to stick to the rules in this class" (Teacher Control) and "New ideas are always being tried out here" (Innovation). The scoring direction is reversed for half of the items in each CES scale.

Despite the wide application and proven usefulness of the LEI and CES, these instruments exclude some of the aspects of classroom environment which are particularly relevant in classroom settings commonly referred to as individualized, open, or inquiry-based. Consequently, the ICEQ was developed to measure those dimensions which differentiate conventional classrooms from individualized ones involving either open or inquiry-based approaches. The ICEQ could be used either on its own in studies focusing exclusively on individualized settings or in conjunction with an instrument such as the LEI or CES to provide coverage of a broader range of classroom characteristics. The initial development of the long form of the ICEQ, which is discussed in detail by Rentoul and Fraser (1979), was guided by several criteria including consistency with the literature of individualized education and salience to teachers and students. Preliminary versions were modified after receiving reactions from experts, teachers, and students and in the light of the results of item analyses performed on data collected during field trials. The final version of the ICEQ contains 50 items altogether, with an equal number of items belonging to each of the five scales. Each item is responded to on a five-point scale with the alternatives of Almost Never, Seldom, Sometimes, Often, and Very Often. The scoring direction is reversed for many of the items. Typical items are "The teacher lectures without students asking or answering questions" (Participation), "The teacher decides which students should work together" (Independence), and "Different students do different work" (Differentiation). The ICEQ is now available in published form which consists of a handbook, a test master set from which unlimited numbers of copies of the questionnaire may be made, and a separate hand-scorable answer sheet (Fraser, 1985e).

The MCI is a simplification of the LEI suitable for children in the 8 to 12 years age range. The MCI differs from the LEI in four important ways. First, in order to minimize fatigue among younger children, the MCI contains only five of the LEI's original 15 scales (namely, Cohesiveness, Friction, Satisfaction, Difficulty, and Competitiveness). Second, item wording has been simplified to enhance readability. Third, the LEI's four-point response format has been reduced to a two-point (Yes-No) response format. Fourth, students answer on the questionnaire itself instead of on a separate response sheet to avoid errors in transferring responses from one place to another. The original version of the MCI contained nine items per scale and is included in the first and second versions of the LEI/MCI Manual. But the reliability of some scales in the original version was less than desirable. Consequently, the third and most recent version of the LEI/MCI Manual contains a new 38-item version of the MCI which has improved scale reliabilities (Fraser, Anderson, & Walberg, 1982). The 38-item version has 6 items in the Cohesiveness scale, 8 items each in the Friction and Difficulty scales, 9 items in the Satisfaction scale, and 7 items in the Competitiveness scale. Typical items in this version of the MCI are "Children in our class fight a lot" (Friction), "Schoolwork is hard to do" (Difficulty) and "The class is fun" (Satisfaction). It can be seen from these examples that the reading level of the MCI is appreciably lower than that of the LEI and is well suited to use among primary school students.

Despite strong traditions of classroom environment research at the primary and secondary school levels, surprisingly little analogous work has been conducted at the higher education level. One likely explanation for this is simply the unavailability of suitable, reliable, and practical instruments for use in higher education classrooms. Consequently the College and University Classroom Environment Inventory (CUCEI) was developed for use in small groups (say, of up to approximately 30 students). The CUCEI is not suitable for use in lectures or laboratory classes, although it may be used where the instructor is involved in lecturing for a relatively minor part of class time. The initial development of the CUCEI involved examining the individual scales and individual items contained in the LEI, CES, and ICEQ. A set of items was written and subjected to the scrutiny of a number of tertiary educators, including some with extensive questionnaire writing experience. After rewriting and eliminating many items in the light of reactions obtained, a trial version of the CUCEI containing 12 items per scale was field tested. The final form of the CUCEI contains 49 items altogether, with 7 items in each scale (Fraser, Treagust, & Dennis, 1986). Each item is responded to using the four categories of Strongly Agree, Agree, Disagree, and Strongly Disagree. The scoring direction is reversed for approximately half of the items in each scale. Typical items are "Activities in this class are clearly and carefully planned" (Task Orientation) and "Teaching approaches allow students to proceed at their own pace" (Individualization).

For each of the instruments listed in Table 1, comprehensive validation information has been accumulated for science classrooms. Some of these validity data are taken from Fraser (1986a) and Fraser and Fisher (1983a) and summarized in Table 2 which reports each scale's internal consistency reliability (using the alpha coefficient), discriminant validity (using the mean correlation of a scale with the other scales in the same instrument as a convenient index), and ability to differentiate between the perceptions of students in different classrooms (significance level and eta^2 statistic from ANOVAs). Table 2 is confined to the student actual form of each instrument and the use of the individual student as the unit of analysis. Data are based on sample sizes of 1,048 students for the LEI (with the exception of mean correlations which are based on 149 class means because no data are available for individuals), 1,083 students for the CES, 1,849 students for the ICEQ, 2,305 students for the MCI, and 127 students for the CUCEI. No data are available on the LEI's ability to differentiate between classrooms.

Table 2. Internal Consistency (Alpha Reliability), Discriminant Validity (Mean Correlation of a Scale with Other Scales), and ANOVA Results for Class Membership Differences (Eta^2 Statistic and Significance Level) for Student Actual Form of Five Instruments Using Individual as Unit of Analysis

Scale	Alpha Reliability	Mean Correlation with Other Scales	ANOVA Results Eta^2
Learning Environment Inventory			
	(N = 1048 Students)	(N = 149 classes)	
Cohesiveness	0.69	0.14	-
Diversity	0.54	0.16	-
Formality	0.76	0.18	-
Speed	0.70	0.17	-
Material Environment	0.56	0.24	-
Friction	0.72	0.36	-
Goal Direction	0.85	0.37	-
Favoritism	0.78	0.32	-
Difficulty	0.64	0.16	-
Apathy	0.82	0.39	-
Democracy	0.67	0.34	-
Cliqueness	0.65	0.33	-
Satisfaction	0.79	0.39	-
Disorganization	0.82	0.40	-
Competitiveness	0.78	0.08	-
Classroom Environment Scale			
	(N = 1,083 students)		
Involvement	0.70	0.40	0.29*
Affiliation	0.60	0.24	0.21*
Teacher Support	0.72	0.29	0.34*
Task Orientation	0.58	0.23	0.25*
Competition	0.51	0.09	0.18*
Order & Organization	0.75	0.29	0.43*
Rule Clarity	0.63	0.29	0.21*
Teacher Control	0.60	0.16	0.27*
Innovation	0.52	0.19	0.26*

Scale	Alpha Reliability	Mean Correlation with Other Scales	ANOVA Results Eta^2
Individualized Classroom Environment Questionnaire			
	(N = 1,849 students)		
Personalization	0.79	0.28	0.31*
Participation	0.70	0.27	0.21*
Independence	0.68	0.07	0.30*
Investigation	0.71	0.21	0.20*
Differentiation	0.76	0.10	0.43*
My Class Inventory			
	(N = 2,305 students)		
Cohesiveness	0.67	0.20	0.21*
Friction	0.67	0.26	0.31*
Difficulty	0.62	0.14	0.18*
Satisfaction	0.78	0.23	0.30*
Competitiveness	0.71	0.10	0.19*
College and University Classroom Environment Inventory			
	(N = 127 students)		
Personalization	0.85	0.33	0.28*
Involvement	0.77	0.39	0.49*
Student Cohesiveness	0.85	0.21	0.37*
Satisfaction	0.92	0.45	0.20*
Task Orientation	0.72	0.35	0.22*
Innovation	0.85	0.39	0.25*
Individualization	0.87	0.24	0.32*

* $p<0.01$

As the LEI, CES, ICEQ and MCI are suited for use in school classrooms, it could be useful to have preservice teachers administer some scales during a teaching practice sessions and to discuss this information when they return to their teacher training institutions. In the case of the CUCEI which is intended for higher education classrooms, it has been found that having preservice education students rate one of their education classes with the CUCEI provides a useful vehicle for introducing them to the field of classroom environment.

Curriculum Evaluation Studies

One of the applications of classroom environment instruments which might be included in science teacher education programs is curriculum evaluation. As one promising use of classroom environment instruments is as a source of process criteria in the evaluation of science curricula and innovations, Walberg (1975) and Fraser (1981b) urge educators more often to incorporate classroom environment dimensions into their evaluations. The use of these process criteria is especially important since it is becoming common for the philosophy of contemporary science curricula and innovations to define, not only the aims to be achieved by students, but also the nature of the learning environment considered desirable (e.g., emphasis on cooperation or individualization). Moreover, Walberg (1975) decries the overemphasis on standard achievement criteria in curriculum evaluation and advises researchers to view socio-psychological classroom processes as valuable ends in their own right. Additionally, several studies of alternative curricula (Welch & Walberg, 1972; Fraser, 1979) have shown that classroom environment variables have differentiated revealingly among the curricula when a variety of cognitive outcome measures have shown little sensitivity. Because of the potential usefulness of classroom environment measures in curriculum evaluation, this section is devoted to reviewing prior work which has included environmental variables among the criteria of effectiveness.

Anderson, Walberg, and Welch (1969) attempted to use students' perceptions on the LEI to differentiate classes using the penultimate version of Harvard Project Physics materials from classes following alternative physics curriculum materials. The sample consisted of 3,264 high school students in 150 physics classes in the U.S.A. The statistical analysis involved multiple discriminant analysis, including rotation of principal discriminant loadings, with the class mean as the unit of analysis. It was found that students in classes using Harvard Project Physics perceived their classrooms as more diverse and democratic, less difficult and goal directed and having a better physical environment and less friction. In another examination of the effects of using Harvard Project Physics materials on the classroom learning environment involving the randomly chosen classes in the original sample, Welch and Walberg (1972) found that students in Harvard Project Physics classes perceived their classes as having greater diversity and less favoritism and difficulty than was perceived by students in classes using alternative materials.

Three different studies have employed student perceptions of classroom environment as criteria in the evaluation of materials developed by the Australian Science Education Project (ASEP). The first study (Fraser, 1976, 1979) employed a modified nine-scale version of the LEI with a sample of 541 seventh grade students in Melbourne to compare the perceived environment in ASEP and conventional classrooms six months after the beginning of the school year. When student socioeconomic status, general ability, and sex were controlled, multiple regression analyses revealed that ASEP students perceived their classrooms as more satisfying, more individualized, and having a better material environment. The second study (Tisher & Power, 1978; Power & Tisher, 1979) traced changes occurring in student perceptions on the LEI and eight scales from the Class Activities Questionnaire (Steele, House & Kerins, 1971) during the use of an ASEP unit in 20 junior high school classrooms. It was found that significant changes occurred on 12 of the 23 learning environment dimensions. In fact, after using the ASEP unit, students perceived their classrooms as having greater cohesiveness, diversity, goal direction, satisfaction, formality, cliqueness, humour, and discussion of interesting ideas and less speed, favoritism, disorganization, and apathy. In the third study (Northfield, 1976), a modified version of the LEI was used in the 17 seventh grade classes to monitor changes during the use of another ASEP unit. When student ability in science was controlled, it was found that significant pretest-posttest changes had occurred for five of the nine environment dimensions considered. After using the ASEP unit, students perceived their classes as more goal directed and individualized and less satisfying, difficult, and competitive.

Similarly, in the Netherlands, Kuhlemeier (1983) and Weirstra (1984) used the ICEQ in evaluating PLON, a new physics curriculum emphasizing inquiry-based teaching methods. Kuhlemeier's data were obtained by administering a Dutch instrument to a sample of 15-16 year-olds consisting of 257 PLON students in 15 classes and 307 control students in 15 classes. MANOVA revealed that, in contrast to control students, PLON students perceived their classrooms as having greater emphasis on participation, independence, investigation, and differentiation. When Weirstra administered a scale based on a translation and modification of the ICEQ's Participation and Investigation scales to 254 PLON students and 144 control students, again it was found that PLON students perceived greater levels of inquiry in their classrooms than did the control students.

Levin's (1980) study reported the use of student perceptions of classroom environment as dependent variables in evaluating an individualized curriculum in 57 first to third grade classrooms in three cities in Israel. Of these classes, 43 served as an experimental group in which an individualized instructional stragegy was implemented, while 14 comparable control classes followed a traditional instructional strategy. Student perceptions were measured with a 45-item instrument measuring the following seven dimensions: Autonomy, Competition, Social Relations, Discipline and Organization, Cooperation, Affective Behavior of Teachers, and Instructional Behavior of Teachers. Results indicated that the experimental and control groups differed significantly on only one of the seven classroom environments scales: students in individualized classrooms perceived greater autonomy than students in traditional classrooms.

Talmage and Hart (1977) reported a study in which the MCI was used as a source of criterion variables in an evaluation study. The experimental group consisted of 23 elementary-school classes in metropolitan Chicago taught by teachers who had participated in a National Science Foundation one-year program on investigative approaches to the teaching of mathematics (e.g., exploring problems in a laboratory setting). This experimental group, together with a control group of 23 classes whose teachers had not participated in the program, responded to the MCI at the beginning of the year in which the program was run and again at the end of the same year. When a multiple regression analysis was performed separately for each MCI scale with the class mean as the unit of statistical analysis, it was found that the group variable (experimental/control) accounted for a significant increment in posttest cohesiveness scores beyond that attributable to pretest cohesiveness scores. The interpretation of this finding was that students in classes taught by participants in the training program perceived their mathematics classes as more cohesive than students in classes whose teachers had not been trained in investigative teaching.

If it is assumed that student achievement measures cannot yield a complete picture of the educational process, then it becomes important that the evaluation of innovations in science education include a wider variety of criterion measures. As student perceptions of classroom psychosocial environment provide a promising source of process criteria of curricular effectiveness, it could be advantageous to include this application of classroom environment assessments in science teacher education programs.

Changing Classroom Settings

Although much research has been conducted on student perceptions of classroom learning environment, comparatively little has been done to help teachers assess and improve the environments of their classrooms. Consequently, this section attempts to encourage and facilitate future integration of this area into science teacher education curricula by, first, providing a review of some related literature and, second, reporting a case study of a successful attempt at using classroom environment assessments to guide improvements in classrooms. In particular, this section focuses on an approach in which feedback information based on student perceptions is employed as a basis for reflection upon, discussion of, and systematic attempts to improve classroom environments (see Fraser & Fisher, 1986; Fraser, 1981b, c, 1985). It involves, first, using assessments of student perceptions of both their actual and preferred classroom environment to identify discrepancies between the actual classroom environment and that preferred by students and, second, implementing strategies aimed at reducing existing discrepancies. This method can be justified partly in terms of recent person-environment fit research which suggests that students achieve better when in their preferred classroom environment (Fraser & Fisher, 1983c).

Very little literature deals directly with the use of student environment perceptions in facilitating changes in classroom environments, but there exists some interesting literature related indirectly to this task. For example, as part of the teacher-as-researcher movement in Britain (May, 1981), curriculum workers such as Stenhouse (1975) and Elliott (1973, 1976-77, 1978) have advocated a mode of action research in which teachers deliberately and systematically reflect upon, discuss and question their own classroom practice as a basis for improving their teaching. Literature devoted to educational program evaluation provides useful guidance about ways in which teachers can play a more prominent role in curriculum evaluation and in the self-evaluation of their own work (Davis, 1980; McCormick & James, 1983). In fact, Bodine (1973) has suggested that teachers engaging in self-evaluation procedures should employ various feedback techniques (e.g., observation by colleagues or use of rating forms) to identify areas in which teachers' classroom behaviors differ from what they consider ideal. Extensive work in England involving teachers in the self-evaluation of their own work has led Simons (1981) to two pertinent conclusions. First, when teachers initially became involved in self-evaluation, they preferred the use of questionnaires to other methods (e.g., observation or interview) for obtaining information about their teaching. Second, teachers required support (e.g., on-site consultancy) to sustain self-evaluation. These observations suggest that two positive features of the proposed approach to improving classrooms are that it involves the use of questionnaires as a source of feedback information and that the researchers provide teachers with some on-site consultancy during the project. Furthermore, the fact that this method for improving classrooms utilizes feedback information based on student perceptions means that use is made of an important but often neglected source of information about classrooms (Weinstein, 1981).

The literature describing classroom interaction analysis and microteaching also provides ideas about the use of feedback to teachers as a means of promoting improved classroom practice (e.g., Olivero, 1970; Dunkin & Biddle, 1974; Peterson & Walberg, 1979). Classroom interaction analysis, which involves the coding of classroom communication (usually verbal) according to category schemes, has been used extensively and successfully in preservice and inservice education as a way of making teachers aware of and subsequently improving their own teaching. Microteaching usually involves the recording on videotape of a teacher's presentation of a teaching episode to a small group of students, followed by feedback involving the teacher, supervisor and peers and, finally, attempts to improve any identified defects in teaching (Brown, 1975). The success of using classroom interaction feedback and microteaching lends some credence to the idea that feedback information based on classroom environment profiles also could provide a useful basis for planning changes in classrooms.

Although there have been very few applications of these methods specifically in primary or secondary school classrooms, analogous techniques involving the use of Moos's Social Climate Scales have been implemented successfully in a range of other human milieus (Moos, 1974b, 1979b). For example, milieu inhabitants' perceptions of actual and preferred environment have been employed in facilitating change through use of the Ward Atmosphere Scale in psychiatric hospitals (Pierce, Trickett, & Moos, 1972; Moos, 1973; Verinis & Flaherty, 1978), use of both the Ward Atmosphere Scale and the Community Oriented Program Environment Scale in a psychiatric hospital (Friedman, 1982; Friedman, Jeger, & Slotnick, 1982), use of the CES in college and university classrooms (DeYoung, 1977; Waters, 1983), use of the Community Oriented Program Environmental Scale in an adolescent residential care centre (Moos & Otto, 1972; Moos, 1973, 1974a) and in alcoholism treatment programs (Bliss, Moos, & Bromet, 1976), use of the Group Environment Scale in staff milieus (Schroeder, 1979), use of the Work Environmental Scale in law enforcement agencies (Waters, 1978) and a hospital burn unit (Koran, Moos, & Zasslow, 1983), and use of the Family Environment Scale in family therapy groups (Fuhr, Moos, & Dishotsky, 1981). Although the above studies are related only peripherally to work in school classrooms, nonetheless, they attest to the efficacy of the general strategy of using environmental assessments to guide environmental improvement and suggest some useful ways of conducting and reporting this type of work.

Because only a handful of applications of these techniques in school classrooms has been published, this section illustrates the proposed methods by reporting one of these case studies in detail. This involved a teacher from a private secondary school in a suburb of Sydney in employing actual and preferred forms of the ICEQ in a systematic attempt to improve the environment of one of his classes. This class consisted of 31 seventh grade boys of mixed ability who were studying several different subjects with the same teacher. The procedure followed incorporated the following five fundamental steps:

1. Assessment. The teacher administered the ICEQ to all students in the class. The actual form was answered first and the preferred form was answered a week later.

2. Feedback. Student data were analyzed by computer by the researchers and presented to the teacher in the form of profiles representing the class means of students' actual and preferred environment scores. During a visit to the school, the researchers explained the interpretation of results to the teacher. In particular, the profiles were used to identify changes in classroom environment needed in order to reduce discrepancies between the actual environment and the preferred environment.

3. Reflection and Discussion. After private reflection and informal discussion with the researchers, the teacher decided to introduce an intervention aimed at increasing the levels of Personalization and Participation in his class.

4. Intervention. The teacher introduced an intervention of approximately one month's duration in an attempt to increase classroom Personalization and Participation. This intervention consisted of a variety of strategies, some of which originated during a number of meetings between the teacher and researchers

and others of which were suggested by examining ideas contained in individual ICEQ items. Strategies implemented to enhance classroom Personalization involved the teacher in moving around the class more to mix with students, asking students about their welfare, praising and encouraging students, chatting with and being warm toward students, and avoiding snappiness. This required some restructuring of lessons so that the teacher had more time for moving around the class. Strategies used by the teacher in attempting to increase Participation were reducing teacher talk, providing more time for students to ask and answer questions, and organizing more group work. In brief, the overall rationale for these strategies was to place greater emphasis on the human element in teaching.

5. Reassessment. The student actual form of the ICEQ was administered at the end of the month of intervention to see whether students were perceiving their classroom environment differently from before. Again data were analyzed by computer and fed back to the teacher accompanied by lengthy discussion about the meaningfulness of results.

The results of the study are summarized graphically in Figure 1, which compares profiles of student actual-preferred discrepancy scores obtained before and after the intervention. These discrepancy scores were obtained simply by subtracting the class mean score for students' perceptions of actual environment from the mean score for preferred environment on each of the ICEQ's five scales. The distances between points on the discrepancy profiles and the horizontal line in Figure 1 represent the necessary increase or decrease in each area needed for the class to become as students would prefer it.

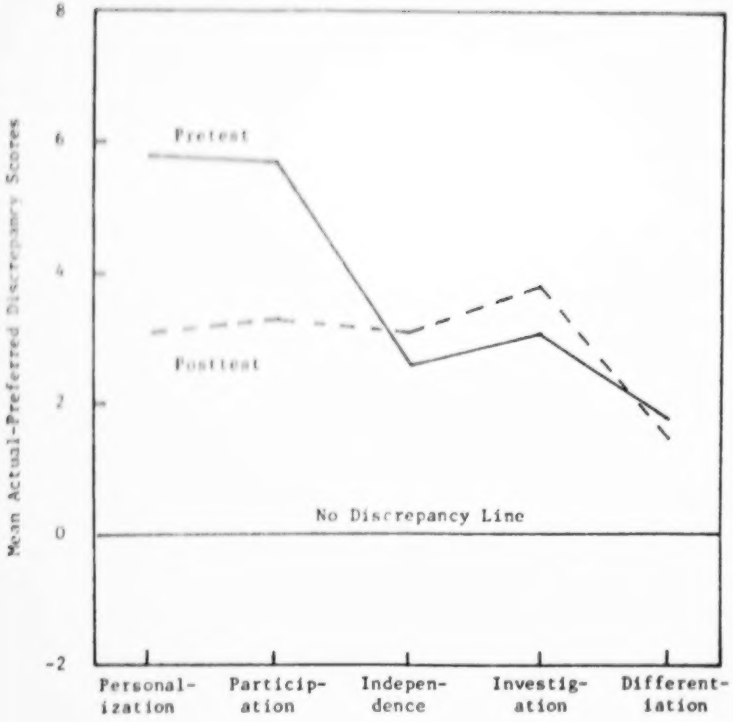

Figure 1. Pretest and Posttest Profiles of Mean Actual-Preferred Discrepancy Scores

Figure 1 clearly illustrates that, during the time of the intervention, an appreciable reduction in actual-preferred discrepancy occurred for the dimensions of Personalization and Participation, but that a negligible change occurred for the Independence, Investigation, and Differentiation scales. These findings are especially noteworthy because the two dimensions on which the appreciable changes were recorded were those, and only those, on which the teacher had attempted to promote change. To further illustrate these findings, a *t* test for dependent samples for the significance of pretest-posttest changes in discrepancy scores was conducted for each scale. (Since only a single assessment of preferred environment was made, these t tests for pretest-posttest changes in discrepancy scores are equivalent to t tests for pretest-posttest changes in actual scores.) It was found that, during the intervention, large and statistically significant reductions occurred in actual-preferred discrepancy on the Personalization and Participation scales, but that negligible changes occurred on the other three ICEQ scales.

Generally, the teacher found that information obtained from administration of the ICEQ was meaningful and that it was possible to identify phenomena in the class which were contributing to the profiles. In particular, the changes in environment picked up through use of the questionnaires accorded with the teacher's intuitive expectations based on student comments and classroom events. These observations are important because they suggest that, in this instance, the ICEQ was able to provide the teacher with feedback information about this class which appeared plausible, which made him aware of specific problem areas, and which suggested starting points for implementing improvements.

Although the case studies reported in this paper and elsewhere (Fraser, 1985a) hold considerable promise, their limitations must be acknowledged in two important ways. First, as each case study involved only one teacher and his/her classroom, more work along these lines is urgently needed to verify the efficacy of these methods of environmental improvement in other geographic areas, in other school subjects, and at other grade levels. Second, because our primary concern was exploring the effectiveness of a newly proposed application of actual and preferred classroom environment scales, we did not pay a great deal of attention to the nature of the interventions which were instrumental in bringing out the observed environmental changes. Consequently, although this paper provides some evidence to justify teachers' confidence in using this approach to changing classrooms, the important task of accumulating detailed information about the nature of the interventions most likely to produce marked changes on particular dimensions of classroom environment has hardly begun. There is considerable scope and need in the future, then, to extend Johnson et al.'s (1984) admirable work in designing strategies for enhancing classrooms cooperation to the design and evaluation of general strategies for changing a classroom's emphasis on a range of other important classroom environment dimensions.

Whereas the case studies reported here and in Fraser (1985a) involved experienced teachers attempting to change their classrooms as part of inservice education initiatives, Lacy, Tobin, and Treagust (1984) recently involved preservice teachers in using a classroom environment instrument to provide feedback about their classrooms. The study involved 40 preservice science teachers involved in three microteaching sessions, each one week apart, with small groups of students which made up a total sample of 180 students from one school. Student perceptions of preferred environment were assessed at the beginning of each microteaching session and perceptions of actual environment were assessed at the end of each session. It was found that students' perceptions of actual classroom environment became more positive over time, thus tentatively suggesting that feedback information about students' perceptions of actual and preferred environment helped preservice teachers to change their teaching in ways which students perceived to be improvements. This preliminary study suggests the potential value of introducing preservice science teachers to classroom environment instruments in order to provide them with a tangible means of obtaining feedback about and guiding improvements in their teaching.

Conclusion

This paper has argued the merits of including the topic of classroom psychosocial environment in the curriculum of science teacher education programs. In particular, discussion focused on the potential of classroom environmental work, first, as a way of sensitizing preservice teachers to important but subtle aspects of classroom life; second, as a source of process criteria of effectiveness in curriculum evaluation; and, third, for guiding systematic attempts to improve classrooms.

It has been assumed in this paper that having a positive classroom environment is an educationally desirable end in its own right. Moreover, the comprehensive evidence accumulated in prior research also clearly establishes that the nature of the classroom environment has a potent influence on how well students achieve a range of desired educational outcomes. Consequently, educators need not feel that they must choose between striving to achieve constructive classroom environments and attempting to enhance student achievement of cognitive and affective aims. Rather, constructive educational climate may be viewed as both means to valuable ends and as worthy ends in their own right.

Given the ready availability of instruments, the salience of classroom environment, the impact of classroom environment on student outcomes, and the potential of environmental assessments in guiding educational improvement, it seems crucial that researchers and teachers begin to include classroom environment instruments as part of the batteries of measures used in school evaluations and school effectiveness studies. It is hoped that this paper ultimately will contribute to a greater awareness of the importance of classroom environment among teachers by encouraging science teacher educators to introduce these key ideas as part of their teacher education programs for prospective science teachers.

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CHAPTER 3

Listening to Teachers Think: Implications for Improving Science Teacher Education

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In this experiment, we "eavesdropped" on a Conversation among a small group of student and master science teachers as they learned about and tried to use two data-collecting instruments adapted from teacher effectiveness research studies (C. Fisher, 1980; T. Good, 1983). It was not our intention to pressure teachers into molds of teaching derived from this effectiveness research. Rather we hoped to trigger dialogue concerning classroom phenomena among the students and master teachers that would be rich in language-specific detail. We were particularly interested in tapping into the processes and content of teacher thinking as the participants in the Conversation reflected on the "doing" of teaching. The purpose of this experiment was to gain insights into more effective ways of preparing novices to understand and think like experienced teachers.

STRUCTURING THE CONVERSATION

The Participants

Nine people participated in the Conversation: three science master teachers (M.T.), Lorin, Vicki, and Joe; their student teachers (S.T.), Emma, Bob, and Bernice; and three professor/researchers. The three master/student teacher pairs taught in different schools in the California San Francisco Bay Area. One setting was a racially mixed eleventh-grade physics class of college-bound students; the second was a ninth-grade general science class of highly transient, multi-ethnic students; the third was an eleventh-grade class of affluent students studying biology in an academically competitive high school. Two of the master teachers had each been teaching for fifteen years; the third teacher was in her second year of teaching. The student teachers had undergraduate degrees in biology, chemistry, and physics respectively. The professor/researchers had been science teachers before becoming academics. Two were the primary professors and supervisors for the participating student teachers; the third was a visiting professor on a sabbatical leave. The professors provided structuring in the dialogue setting but purposefuly restricted their verbal participation in the Conversation.

Parity

The Conversation was structured to optimize the possibility that parity would exist between student and master teachers during the Conversation. Both groups were equally ignorant in the use of the research coding instruments, the instructional content to be learned by student and master teachers. Student teacher verbal domination during the conversation was anticipated because the students alone knew the majority of the participants in the Conversation; their professor/supervisors, their master teachers, and each other. The students had interacted intensely in many situations during the four months preceding the conversation: they had spent four days with their professors and peers on a retreat in the mountains, shared the anxieties associated with their first student

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teaching experiences, and studied and socialized together. The three master teachers had never met each other and knew only their own student teacher. The Conversation setting was totally foreign to the master teachers though it was familiar to the student teachers, as it was the classroom for all of their college classes.

The Plan

In order to precipitate dialogue among the small group of student and master teachers participating in the Conversation, the professor/researchers offered to introduce and train the group in two observational coding schemes derived from the teacher effectiveness research related to Tom Good's Active Teaching Behaviors (ATB) and D. Berliner and C. Fisher's Academic Learning Time (ALT). The task of the group during the Conversation was to code videotaped lessons from the participating teachers' classrooms using the ATB and ALT forms.

Preparations

In anticipation of the Conversation, the researchers set up separate appointments with each master/student teacher dyad to invite them to the "training session." The professor/researchers told each dyad that they were invited to a session that was designed to "introduce you to coding forms that look at teacher behaviors and student behaviors. You will get a brief idea of what they're about and will have a chance to try using them as you code from videotapes of your classroom. We are interested in introducing these materials to you and, to the extent that you're interested in them, providing whatever help we might to you in the use of them. We're not asking you to change your teaching. We're interested in your honest rections to what you see, so that when we finish we can have some feeling as to whether this is something that might be useful. If it does lead to an attempt on your part to try something different, we'd be interested in what you try, and if it works or not." All three dyads agreed.

In addition to the three meetings with the participants to invite them to the "training session," the researchers visited each of the three classrooms a second time prior to the Conversation. They collected data during science lessons, using the two coding instruments in order to have realistic teaching examples from the participants' classrooms available on the evening of the conversation. Each student and master teacher dyad was requested to bring a videotape of their classroom teaching to the Conversation for use in the practice coding. Every effort was made to bring as much as possible from the participants' classrooms to the Conversation so that the media for dialogue would be from a familiar base.

The Setting and Agenda

The conversation took place from 6:00 to 9:00 in the evening at the student teachers' college. A large comfortable room with a fireplace, blackboard, round table that easily accommodated the nine participants, and video screen for viewing the taped lessons provided the environment for the Conversation. An informal relaxed atmosphere prevailed: food and drinks were available when the participants arrived and throughout the Conversation.

The three-hour session was divided roughly into six parts: (1) Getting acquainted, (2) Discussing the Academic Learning Time (ALT) research and introducing the coding instrument forms, (3) Practicing coding from videotapes using the ALT instrument, (4) Discussing the Active Teaching Behavior (ATB) research and introducing the coding instrument forms, (5) Practicing coding from videotapes using the ATB instrument, and (6) Wrapping up the Conversation.

The Training

The first research coding instrument to be introduced in the Conversation was derived from the ALT research and focuses on student behaviors. It utilizes a time-sampling procedure for direct observation of selected students for fifteen-second intervals. The student behavior is then noted in terms of Academic Engagement and Accuracy of Student Responses. There are three possible categories of engagement from which to select: **Engaged** (the student is actively processing academic information), **Non Engaged,** or **Interim** (refers to nonacademic tasks that are part of the lesson, such as pencil sharpening or getting books). In the area of student accuracy, the observer must decide if the student activity during the engagement is **Accurate, Inaccurate,** or Covert (not possible to determine). There is also a category for the observer to note whether the student is responding **Orally, In writing,** or **Using manipulatives.**

The second research coding instrument to be introduced in the Conversation was derived from the ATB research and focuses on teacher behaviors. It also uses a time-sampling procedure for coding observations of teachers involved indirective teaching strategies. The teacher is observed for thirty seconds and then his or her activities are coded into one of twenty categories that best describes the major activity during that period. In addition, space is provided for "description" so that the observer can note specifics during the time interval. The twenty categories are divided into four units: Lesson Introduction, Instruction, Closure, and Classroom Maintenance. Under each category is subsumed specific behaviors most frequently found among outstanding math teachers in Good's studies. For example, under the Introduction category are: (1) states goals and objectives, (2) outlines lesson, (3) explains concepts or defines items, and (4) reviews previous instruction.

DESIGN AND DATA

The design and resulting data from this experiment consist of: (1) audio recordings and typescripts of interviews with the master-student-teacher dyads three weeks before the Conversation; (2) typescripts from audio recordings of the Conversation; (3) master teachers' and student teachers' coded observations of their science students within three weeks following the Conversation (the number of observations to be individually determined); (4) three open-ended individual descriptions of science students by the student teachers within six weeks following the Conversation; and (5) audio recordings and typescripts of post interviews with the master teachers form the basis for this descriptive study.

RESULTS

Griffin (1984) suggests that teacher knowledge is for the most part unarticulated; beliefs often override acquired information. We were interested in learning about teacher knowledge and the thinking processes teachers use as they are actively engaged in teaching. This experiment was designed to precipitate teacher "thinking-in-action" by simulating real-time, classroom decision-making situations. Conversation participants were forced to make classification choices from videotaped scenes in a moving time frame. Evidence for the existence of an extensive teacher knowledge repertoire and shared thinking processes follows.

EVIDENCE FOR THE EXISTENCE OF A COMMON TEACHER KNOWLEDGE REPERTOIRE

The Conversation elicited stark contrasts between student and master teachers in: (1) the volume of talk, (2) the interactive form of the dialogue, (3) the linking of new knowledge, and (4) hypothetical-experimental thinking. These differences suggest the availability of a knowledge reservoir on the part of master teachers that is unavailable to novice teachers.

Volume of Talk

Master teachers dominated the talk: they accounted for 80% of the dialogue during the entire structured Conversation; the student teachers talked 10% of the total time. The remaining 10% of the talk consisted of input and structuring by the professor/researchers. The concept of parity between student and master teachers as they practiced applying the research categorizations to classroom situations was nonexistent. Verbally and intellectually, the master teachers completely dominated the Conversation.

Interactive Dialogue

The master teachers argued, talked, laughed, and "rolled ideas back and forth" in their attempts to select the category that best fit the behavior. Clearly they were engaging in a very familiar activity: on-the-spot decision making. An example of this interactive dialogue among the master teachers follows (the words in bold type are category names on the coding sheets):

Vicki (M.T.): So...that was...(pause as she's trying to figure out which teaching behavior to code) ...directions (said almost inaudibly).
Joe (M.T.): Yes, that was really maintenance (said with positive conviction) really getting the class started.
Lorin (M.T.): It was kind of class rules.
Joe (M.T.): Well, she restated a rule and then gave direction.
Vicki (M.T.): So the major focus then was restating class rules or may be told to attend.
Lorin (M.T.): Told to attend.
Joe (M.T.): Yes, I think it is told to attend.

A consensus was reached; each master teacher initially selected a different teaching behavior category. As they continued to think and discuss out loud, an entirely new category was identified that all agreed captured the teacher behavior most closely.

Although confidence and high engagement characterized master teacher behavior during the entire Conversation training session, student remarks were tentative and surprisingly timid. Student teachers seldom initiated a behavior-classifying suggestion, whereas master teachers vied to be the first with an idea. The student teachers characteristically mentioned only one possible categorization and then ceased talking. Many times they appeared to be waiting expectantly to see if their suggestion was the "right answer."

Linking New Knowledge

The master teachers reacted to the novel, problem-solving challenges presented in the Conversation training session by thinking of practical "spin-off" applications that could be applied in their day-to-day teaching. Framing the coding activity in this manner suggests a linking of new information to pre-existing knowledge. The following quotes are from master teachers in response to the question posed at the beginning of the Conversation concerning their memory of the purpose of the evening as explained by the professor/researchers in the pre-Conversation interview.

Vicki (M.T.): Well, I think I heard basically the same thing that Bob (S.T.) said and then maybe took it one step farther thinking, "Gee, as a second-year teacher maybe this is something I can use. So if it's great, I'll go ahead and use it." At this point in time, I'm just interested in getting my hands on any kind of tool I can. Also, I've been a little frustrated myself with just observing Bob (S.T.). How can I be most objective in my approach as a master teacher and try to cover as many bases as possible with Bob feedback-wise?

Joe (M.T.): ...it sounds interesting and useful. Having had a number of student teachers over the years, I've wished I could have something to direct my attention because I have a number of things that are distracting to me. There are so many different things in the teaching process, and every time I have a student teacher I have to rethink so many things. I look at this as a learning process for myself because otherwise I don't think about some of the things I do...you know, why are these good techniques or what do I do in the classroom?

References to "covering a lot of bases" and "there are so many things in the teaching process" suggest the awareness of a fairly extensive professional knowledge base. In fact, in Joe's case, the knowledge seems to be at a subconscious level, something he doesn't actively think about unless required to, as with a student teacher. The teachers' comments also suggest difficulties in verbally articulating teacher knowledge to student teachers.

Student teachers, in contrast to the master teachers, did not appear to have the internalized knowledge base available for linking. Rather, they framed the coding activity in terms of internal expectations. The following are examples of quotes from the student teachers in response to the question posed at the beginning of the dialogue: "What do you remember hearing described when we invited you to this Conversation?"

Bernice (S.T.): To tell you the truth, I don't remember anything except for the checklist, you know, check out behaviors. Sounds awful.

Emma (S.T.): I remember, wait...may I ask some questions? Are you going to be asking us to do certain things, I mean besides just the checklist as far as my teaching goes or can I just go on teaching the way I've been teaching?

Bob (S.T.): Well, I remember that you needed some of the secondary people to help you out with it and it was something you wanted to try with both the teachers and the students.

At the conclusion of the training, the student teachers had the following comments:

Emma (S.T.): Is this going to last till the end of the semester? Do we have to use these forms till then?

Bernice (S.T.): So does that mean you don't want these back, these data sheets back?

Student teachers appeared to link the usefulness of newly acquired skills and information to the meeting of externally perceived expectations from authority figures. A possible explanation for this type of student thinking may be the lack of an available practical teacher-knowledge base to draw on and add to.

Hypothetical-Experimental Thinking

A flood of questions emerged from the master teachers about the specific use of the coding instruments in hypothetical situations. These "what if..." questions require an informed knowledge base from which to think about the unknown but possible. The following two examples were selected to illustrate this point:

Joe (M.T.): During the accuracy coding, what if the student's thinking?

Vicki (M.T.): What if you're trying to do some overt responses from the class, trying to maybe check for understanding and you're asking students to say do thumbs up, thumbs down. Is that manipulative or is that considered oral?

An example of teacher experimental thinking was described by one of the master teachers in the post-conversation interview.

Researcher : Are these the same students but rearranged?

Joe (M.T.): Same students, yes. I put them boy-girl, boy-girl just to see what would happen. So far it is working fantastically. It's a real interesting experiment. Except for one. Davis - he just didn't work with anyone else.

Researcher : Was that the boy I looked at that day who was never on task?

Joe (M.T.): That's the one. You know, it would be interesting to give him the form to fill out on four other kids so he could see from observation what other people do with their time in here. It would be interesting in itself to see his response. I might try that.

It should be noted that there were no hypothetical or experimental suggestions or comments made by the student teachers during the Conversation. Perhaps these more formal, abstract thinking patterns require a significant base of concrete experiences, as yet unattained by the novice teachers in their practice teaching.

TYPES OF TEACHER THINKING-IN-ACTION PROCESSES

Two thinking patterns emerged in the Conversation experiment and are referred to as reading signals and simultaneous part-whole processing. These processes were used extensively and understood by all three master teachers. Although the student teachers were doing some signal-reading, it was not as developed or used as frequently as by the master teachers. The part-whole processing, as noted by the master teachers in this section, is particularly difficult for student teachers.

Reading Signals

Master teachers made extensive use of visual clues in selectively observing classroom phenomena. They referred to this process in their discussions as "reading signals." The physiological focus was most often the head, face, and upper body, probably because these parts of the body were the most observable data available to the teacher as she/he moved about the classroom. The following four episodes were recorded from master teacher comments as they classified videotaped student behavior as "engaged" or "nonengaged."

Episode I

Vicki (M.T.): Well, that's hard because all she's doing is correcting a review paper, so you have no idea whether she's engaged or not.

Episode II

Vicki (M.T.): You can't see the head so we have no idea if she's watching the person who is responding.
Lorin (M.T.): Of course the body language says some things.
Vicki (M.T.): That's true; the shoulders, arms.
Lorin (M.T.): The hands.

Episode III

Joe (M.T.): I'd say she's looking up at Bob.
Lorin (M.T.): Yeah, it's very subjective but I think her mind was on something else just watching her eyelids.
Vicki (M.T.): It was like I'm supposed to be watching the speaker so I'll look in that direction but I'm thinking about something else.
Lorin (M.T.): There was some changes in focus...slight movements of the head.

Episode IV

Vicki (M.T.): That's a "cool" behavior.
Lorin (M.T.): Yeah.
Vicki (M.T.): And that doesn't necessarily mean that he's not engaged...it's a posture but it doesn't mean that he's not there.
Lorin (M.T.): You can't really see the faces so you can't tell.

The teachers collected information from students' head movements, shoulders, arms, hands, eyelids, and faces. The attending to the detail of nonverbal, sometimes rather subtle behaviors, suggests that teachers may have internalized coding that helps them collect data and organize it in order to make instructional decisions quickly and accurately.

Simultaneous Part-Whole Processing

A shared pattern of teacher thinking, a common way of "seeing" in the classroom, emerged during the master teachers' Conversation dialogue. Vicki (M.T.) referred to it when she said, "That's what you get with teachers you know, they have a third eye...or sense of something...eyes in the back of their head." Joe (M.T.) said a similar thing in response to one of the researcher's questions in the post-Conversation interview concerning Joe's classroom use of the ALT student coding form.

Researcher : Did you find it frustrating not to be looking at the rest of the class while looking at those four students (while using the data collecting instruments)?

Joe (M.T.): No. No, it didn't bother me at all. I focused in on them. I've never been able to do that before. You know normally you're more sort of involved in the whole thing. And I think this is one of the hard things; it becomes second nature to a teacher who's taught a while and a hard thing for a young new teacher. And that is to be aware of everything. I mean you're looking at a whole picture. And it's the kind of thing where you're standing over here and you know what he's doing over there because you've got eyes in the back of your head kind of thing.

Classroom thinking-in-action requires teachers to simultaneously keep track of individual students and the entire group. Data from these multiple sources must be carefully weighed to determine which course of action to take at any one moment in time.

Simultaneous events taking place in different parts of the classroom environment, in combination with the need for teachers to make numerous on-the-spot decisions, force a kind of thought processing that is dramatically different from researchers' reasoning. Researchers systematically and laboriously collect numerous data points before making decisions and generalizations. In the Conversation, the master teachers quickly interpreted from just a single data point. This practical thinking-in-action processing allows teachers to dynamically affect ongoing teaching episodes.

IMPLICATIONS FOR SCIENCE TEACHER EDUCATION

In the Conversation experiment in this study, student and master teachers were forced to "see" and "think" about classroom phenomena using researchers' lens. As the experienced and novice teachers watched videotapes of their classes, they tried to classify their own behaviors and those of their students using categories derived from teacher effectiveness research. Master teachers thought "out loud" as they struggled to make choices about the interpretation of specific student or teacher actions. In the process, teachers' thinking-in-action became overt. The surprising lack of involvement on the part of the student teachers appeared to be due to their inability to generate ways to think about teacher thinking.

This experiment strongly suggests two possibilities for strengthening teacher preparation programs in order to enhance students' capability to think, understand and act like professional teachers. The first idea involves the use of videotaped episodes from student teachers' classrooms for the purpose of building a solid repertoire of practical experiential knowledge. The second suggestion relates the powerful effect of dialogue among student teachers, master teachers, and science education professors about relevant research. The underlying force in both the videotaped classroom episodes and the research dialogue with master teachers is active reflection on teachers' thinking-in-action. A desirable goal for science teacher preparation programs is to lay the groundwork so that in time the students can think formally, in the Piagetian sense, about their own teaching. Implications from this study argue for the inclusion of the following approaches in structuring college classes on science instruction to facilitate this goal.

Videotaped Episodes from Student Teachers' Classrooms

The first idea suggested by the Conversation experiment is the inclusion of videotape analyses in the curriculum. There are two environments in preservice teacher education in which a student can potentially begin building a strong teacher knowledge base: methodology courses and student teaching. Methods courses are conducted "at-a-distance" from real classrooms so discussions lack the rich, vivid details, complexities, and pacing so essential to indepth analyses. Student teaching is the obvious place to learn what and how teachers think; unfortunately reflective conversations rarely occur. Time pressures, a paucity of language for detail-specific talk, and lack of professional precedent explain the absence of student and master teacher discussions on teacher thinking-in-action.

Interactive viewing of videotaped segments from the student teachers' classrooms can dynamically affect the acquisition of practical knowledge related to teacher decision making and thinking. Instant replays, freezing-an-action, and temporarily putting the class "on hold" are all possible with this media. Student teacher control over the classroom flow provides opportunity for reflective discussions in the presence of concrete, actual situations in "real time." Engaging with master teachers in this reflective process provides the possibility that students can tap into and listen to teacher's action thinking. Interacting with other student teachers in this process is the beginning of teacher collegiality in which discussion of classroom detail is the norm.

Piagetian theory suggest that in order to move from one level of understanding to the next, confrontation or disequilibrium, in combination with reflection, is required (Bowyer and Karplus, 1979). Imposing forced choices on teacher-thinking in the Conversation tasks described in this study precipitated argument, discussion, and mental activity that is consistent with the disequilibrium involved in reflection and naturalistic learning. Teachers were frustrated by aspects of the observation instruments that from their viewpoint, at times filtered out important information or conversely, yielded superfluous data. Yet, confrontation and reflection occurred. It is suggested that demanding problem solving tasks coupled with the videotaped teaching episodes that require action decisions be included in science education coursework. Thinking in context about teacher-thinking will stimulate new understandings concerning the art and skill of teaching.

Using both unstructured discussion and focused activities that demand active processing of the video data offer student teachers opportunities to add practical knowledge to their classroom-thinking repertoires. In the focused viewing, student teachers can choose to concentrate on instructional strategies, content learning, or specific students. Video viewing tasks can be designed that demand students' active engagement in classifying (example: questions), serial ordering (example: direction instruction), or part-whole thinking (example: look at the effects of the concluding class activity in relation to the initial advanced organizers). There is also the possibility that student teachers can actively engage in "what if" thinking by comparing what actually happens in the taped classroom episode with "what might be" if another strategy were used. The alternative idea can be partially played out by relooking at the tape to see if the limiting problems related to the initial strategy would in fact be addressed in the new approach. This reflecting on and analyzing concrete experiences using the context-familiar classroom videotapes perhaps can provide a base for the teachers to eventually think in formal operational terms about their work.

Dialogue Among Student Teacher, Master Teachers, and Science Education Professors about Relevant Research on Training

A second implication suggested by this study is the inclusion, in science education instruction, of carefully structured dialogues among student/master teachers and science education professors concerning relevant research. Teachers and researchers in the process of doing their work both actively observe and interpret classroom phenomena. What they see and how they use their observational data of course differ: teachers teach students and researchers add new knowledge to the field by empirically developing models for use in prediction and interpretation. There appears to be potential, if these discussions are properly designed, to change students' and master teachers' understandings of the processes and practical use of educational research.

Listening to teachers in this study argue and discuss, as they attempted to adapt their professional thinking to fit the researchers' molds, highlighted gaps between teachers' and researchers' knowledge domains. Joe, one of the master teachers, said it very clearly. When asked what he remembered about the invitation to learn about the research instruments, his response was, "Well, actually, I haven't thought about it much...(pause)...I've sort of been in another world."

Teachers appear to have little knowledge concerning how educational research is supported, conducted or used. At the beginning of the Conversation, in an effort to make connections with the research instruments to be used later in the evening, the question was asked, "Does everybody know about the Far West Educational Research Lab?" The answer in unison was, "No." After a brief explanation, Lorin, one of the master teachers, asked, "Where is it actually located?" In fact, that particular research lab is located just ten miles from where the Conversation participants were sitting. The student and master teachers were equally ignorant concerning the National Institute of Education and the National Science Foundation. Clearly, educational research literacy needs to be functionally addressed early in a teacher's professional preparation.

The teachers in this study were visibly distressed in terms of the discrepancies between student data collected using the research instruments and student data they collected in the process of teaching. An example of this occurred during the Conversation. All of the teachers agreed that the student behavior they were coding could easily be classified as **nonengaged.** However, in the ensuing discussion it was revealed (by the person who taught the lesson) that although the student appeared **nonengaged,** in fact, "at the end of the lecture this student summarized it very well. He really knew in detail what was going on."

In another example, master teacher Lorin was struggling to code a particular student response in terms of **accurate** or **inaccurate.** "In physics it would be kind of difficult to code this. I watch kids and often I can see a great deal of what they're doing is not quite right; some of it I've explained and they didn't get and some of it, ha, I never thought that anybody would do it that way." Everyone laughed knowingly.

Then Vicki added, "I kinda see what Lorin's point is. In science a lot of times you learn so much more by being inaccurate and learning from your mistakes or from experimenting with a technique and coming around from behind sort of to figure out what you're doing. And that's the fun of teaching science: to watch kids try all these things before they kinda figure out what works for them by coming onto the 'accurate.' Is that inaccurate science teaching technique?"

Another area where teacher and researcher knowledge differs is in reference to the collection of data. Researchers systematically collect data points over relatively long time periods and the teachers nonsystematically collect student data in short spurts. Researchers use their data to generalize to larger populations; teachers use theirs to make on-the-spot educational decisions. Teachers accumulate data on an individual by storing sporadically collected bits, over time, in the memory. An emerging picture of a student gradually becomes more complex and complete. However, at any one point, the teacher must use what's available to make a decision; observations instantly become interpretations. This is the essence of the art of teaching. Knowledge about the nature of the differences between researcher and teacher data collection and generalization can and need to be taught through example in videotape analysis sessions in preservice science education classrooms.

Teachers in this study were distressed over the apparent conflict between what they "see" in a classroom and what researchers "see." The master teachers felt nonvalidated in terms of the researchers' data collecting processes. Joe, one of the master teachers, expressed the consensus view as follows: "But you know, the one thing that I miss here (in this data collecting process) that is very much a part of my enjoyment in teaching science is, you have a kid and he's not in the lesson. I mean, mentally he may look like he's finished; he's off exploring. But, he really might be doing science, he might be really being involved. He may not write up his material; it's home or something else. But still, you know he may be discovering things. And once in a while, you'll see him and he'll say, 'Hey, come and look at this...see what I found!' And to me, that is a very enjoyable thing in science teaching. (pause) And yet, he would have to be coded nonengaged."

The inclusion of carefully designed dialogues among student and master teachers and professors can potentially demystify issues relating to research methodology. In terms of applying classroom research, it is clear that this knowledge on the part of teachers is needed. Teachers in the study who were confident in making decisions concerning the videotape classifications suddenly became confused and anxious when faced with the prospect of actually using the instrument with their student teacher in the classroom. The master teacher Lorin, for example, was trying extremely hard to figure out how to "correctly" select a sample to use in the coding. Even though he was assured that he should pick students about whom he wanted more information, the common sense and confidence he displayed earlier in the evening was replaced by continual doubt. Use of educational research tools by teachers needs to be explored in the context of preservice education to understand their limitations and practical advantages.

At one point in the Conversation, when the ATB coding sheet was being described, the master teacher Vicki asked with regard to writing the running verbatim description, "Do you do this for a certain period of time like ten minutes and then stop and rest?"

One of the researchers responded, "No, just go forty minutes or whatever. One of the master/student teacher pair can teach and the other code."

Vicki responded in all seriousness, "Well, I know what I'll choose!" All the teachers laughed in agreement. The Conversation experiment strongly suggests that researchers and teachers take into account the differences in their worlds so that the valuable flow of ideas between the two will not be falsely judged because of miscommunication. Educational researchers and teachers need each other.

This experiment suggests that it is the constructs derived from research that may be most useful to teachers. Analyses of the student teachers' open ended, self-structured observations of students and teachers six weeks after the structured Conversation indicate that these constructs can be learned and applied. In the student teachers' running classroom narratives written six weeks after their training in the use of ATB and ALT instruments, concepts like engaged or non-engaged, interim, accurate or inaccurate, and closure or maintenance appeared frequently. Observations were organized in terms of time sampling. Master teachers openly expressed a desire to use the constructs. Master teacher Vicki said during the conversation, "You know, I wish we'd kept that videotape from our class when we did Jeopardy (a math activity game her student teacher devised). I would like to see it again since we're actually looking at engagement and non engagement." This suggests that the constructs have a usefulness for teachers.

CONCLUSION

Science education professors engage in the extremely difficult task of assisting students in their transformation from novice to expert. The professional reality is that once the students become teachers, isolation from direct work with colleagues dictates that continued professional development becomes a do-it-yourself proposition. The year of preservice work is an opportunity for students to actively build an experiential knowledge repertoire.

This study suggests that student teachers need to actively build a substantial base of concrete experiences to draw from before they can begin to think in "teacherese." As teachers, of course, they will build this knowledge repertoire on-the-job as they struggle to orchestrate and manage classroom uncertainties. However, if teacher educators can devise a means for student teachers to begin construction of teacher-frames-of-reference during the preservice year, the transition from novice to expert will be enhanced during the initial years.

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CHAPTER 4

Innovation in the Preparation of Elementary School Teachers in Science

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BACKGROUND INFORMATION

SODIA-Science is the science component of the SODIA Elementary Teachers Preparation Program at Utah State University. The present program has evolved since 1971 when initial efforts were made to develop an elementary teacher preparation model that met the needs of students and had a sound basis in theory. The acronym SODIA is derived from the initial letters of descriptive words (Self, Others, Discipline, Implementation, and Associate Teaching), which describe the emphasis placed at each level of the program.

SODIA-Science was one of seven programs recognized in the 1985 National Science Teachers Association Search for Excellence in Science-Preservice elementary Teacher Preparation Program. SODIA met all NSTA standards for excellence. In 1985, SODIA-Science received a three-year U.S. Department of Education grant under the Synthesis and Use of Research in Education Project. The purpose of this funding was to identify and document research-based approaches to improvement of teacher education.

Science component innovations include a strong science content foundation, pretesting with remediation, computer mediated instruction, flexible completion times, a convocation, and a strong practicum. Students are pretested upon entry into the science methods course. Subcomponents of the pretest include life, earth/space, and physical science content knowledge, science process skills, and science attitude. Students scoring less than 80% competency in any subcomponent must undertake remediation in that area. Remediation procedures are individualized and include video tapes with study guides.

Practicum experiences are coordinated with computer-mediated curriculum resources. This procedure acquaints students with CMI technology and provides resources for teaching science in their practicum.

This chapter documents the process by which SODIA-Science was developed and outlines the accompanying products of the process.

PHILOSOPHICAL FOUNDATION

The initial step in providing a foundation for a science methods course was a review of literature. This process provided an array of material that ranged from being of interest to that judged of no value to this project.

Initial searches included anything that might have related to an elementary science methods course. The mass of information was then reviewed for messages for curriculum improvement. The section that follows briefly outlines some of the reviews and how they impacted the science methods course.

Researchers have long been dismayed by the apparent misconceptions about science held by students (Bady, 1979; Cooley & Klopfer, 1963; MacKay, 1971; Mead & Metraux, 1957; Rubba, Horner, & Smith, 1981) as well as about the misconceptions possessed by science teachers (Carey & Stauss, 1968, 1970; Miller, 1963; Schmidt, 1967). It seems logical that improved student conceptions would necessarily follow if programs were designed to improve science teachers' conceptions of science. Such programs (e.g. Billeh & Hassan, 1975; Carey & Stauss, 1968, 1970; Welch & Walberg, 1968) assumed that a teacher's classroom behavior is influenced by his/her conceptions of the nature of science and that a significant positive relationship, therefore, exists between teachers' conceptions and changes in the conceptions of their students. However, research (Lederman, 1983) has failed to support this intuitive notion. In addition, curricula specifically designed to promote improved student conceptions of the nature of science have provided only limited success.

A NSTA position statement (1983) recommended standards for the preparation and certification of elementary science teachers. Much of the rationale for the stated NSTA standards is similar to the rationale for the USU methods course. The NSTA statement indicated that there is universal agreement that elementary teachers should have reasonable knowledge of science content. The first recommended standard reads as follows:

> All colleges and universities should require a minimum of 12 semester hours or 18 quarter hours of laboratory or field-oriented science including courses in each of these areas: biological science, physical science and earth science.

Griffiths (1976) in studying college chemistry and physics students, determined that only about 30% were at the formal operations level. This finding compares favorably with work done by McKinnon and Renner (1971) in which they determined that only 25% of college freshmen in their sample were already at the formal stage. Another study by Lawson and Renner (1974) produced similar results. Elementary education majors may be functioning at an even lower percentage level (Lawson et al, 1975).

A success-oriented science program must accommodate student ability. Content and methods course students should have concrete experiences as dictated by the fact that most are not at the formal operations stage. However, success in science methods alone may not be sufficient to motivate students to teach science. Bandura (1977) has described a theory of "self-efficacy" which suggests that if a student attributes success to luck rather than to ability and effort, success may not lead to greater interest and effort in the future. Students should experience the methods course in such a way that they can attribute their success to personal effort and ability.

In an attempt to relate teaching behavior and classroom climate to students' conception of science, Lederman (1986) identified four variables as "generic" by virtue of their pervasive importance with respect to conceptions of science. They were:

1. The teachers/classes of the "high" group were typically more pleasant and supportive.
2. The telling of anecdotes, use of humor, and instructional digression by teachers was more evident in the "high" group.
3. The "high" group had dynamic teachers.
4. The "high" group classes employed a variety of instructional media.

Other variables identified in the study may be considered prerequisite variables since they facilitate learning when present. They include:

1. Frequent questioning.
2. Questions of a higher cognitive level.
3. A problem solving approach.
4. Sequential probing of student responses.
5. Relating subject matter to students' lives.
6. AAAS guidelines (AAAS, 1970) indicate that courses should be related to the science the students will eventually teach.

The above factors speak for a sound foundation in science that is taught in other than the traditional lecture approach. Coupled with this, in 1980-81, there was a general consensus that elementary teachers had a very poor background in science. Locally, less than half the elementary teachers were teaching any science. Most had little or no science content background and although graduation requirements specified 19 quarter hours of science, the courses were not specified. Nature study was as acceptable as biology, and astronomy was as acceptable as introductory physics.

It is almost self-evident that what interests one person may not interest another (Cronbach and Snow, 1977). The case for a partially individualized approach to teaching may be based on the following assumptions:

1. A stimulating environment with an enthusiastic teacher is prerequisite to learning.
2. If given a choice, students will avoid unpleasant experiences and choose pleasant ones.

Piper (1977a) identified four science methods course characteristics considered important by preservice elementary teachers. They were: (1) competencies to be mastered in the course were publicly stated; (2) the instructors modeled the behaviors which preservice elementary teachers were expected to demonstrate; (3) campus activities were planned to assist preservice elementary teachers in having successful field experiences; and (4) instructors provided personalized feedback following field experiences.

Piper (1977b), in another study of science methods courses, also found that stated competencies and field experiences were ways to produce more positive student attitudes toward science.

Katona (1940) identified the strategy of "learning by help." This process focused on principles that must be considered in solving problems. Whimbey (1977) indicated that when the instructor "thinks aloud" to facilitate student understanding of strategies, errors in student thinking will become more evident. The above components contribute to a philosophy best exemplified in the "helping relationship" approach.

The essence of the "helpig relationship" approach is that a learning experience should be a joint enterprise of students and teachers attempting to identify and practice ways of relating to each other as real persons in a creative setting (Rogers, 1961, 1963a, 1963b; Faw, 1949, 1957). The basic ingredient in the "helping relationship" approach is people.

Various strategies for problem solving may be utilized in the "helping relationship" situation. Affective considerations include:

1. The student must desire solution.

2. The student must feel he/she has the ability to solve the problem.

3. The student must desire to begin an attack on the problem.

Working in small groups definitely facilitates problem solving (Suydam and Weaver, 1977). These components of research on problem solving can justifiably be applied to the science methods course, with the criterion for application: does the component help create an environment conducive to problem solving? Studies by Brownell (1942), Maier (1970), Simon (1976), and Wheatley (1977) have contributed to structuring problem-solving situations in the methods course.

The logic of a curriculum framework consisting of goals and objectives may never be perceived by the student (Ausubel, 1963). However, research suggests that students need to know what is expected of them (Baker, 1969; Duchastel & Merrill, 1973; Gleit & Elington, 1978; Heron, 1971; Kibler et al., 1970). The more freedom students have in the learning process, the more important objectives are in facilitating learning. These factors suggest that there is merit in providing the student with objectives and an explanation of the process involved in achieving the objectives.

COLLABORATIVE EFFORTS

The SODIA program has a tradition of collaboration extending back to 1971 when the Utah State Office of Education, teachers and administrators from three local school districts, and Utah State University faculty of education formulated the initial program. This process has been expanded to form the Teacher Effectiveness Project (TEP), funded by the Mellon Foundation and directed through the College of Education. Components of the project include the Northern Utah Curriculum Consortium, Edith Bowen Elementary Teacher Education Laboratory School, and the Utah State Office of Education. The Consortium consists of 11 educational institutions. A major goal of TEP was to assist school districts and teacher preparation institutions in enhancing the effectiveness and retention of beginning teachers.

Preliminary collaborative SODIA-Science efforts were initiated in June, 1983, when an informal discussion of the status of elementary science teaching was carried out among science and education faculty. This group evolved into a more formally constituted Advisory Committee in June, 1984, and was further expanded in June, 1985, to include the Dean of the College of Education, the Dean of the College of Science, Heads of the Elementary Education, Chemistry, Physics, Geology, and Biology Departments, four science faculty, an education faculty, 12 public school teachers and administrators, and four students. This group is now functioning as a voluntary, unpaid advisory group and meets twice a year to review the program.

The first official act of the advisory group was to examine the review of literature provided by the project director and select those items that seemed to say something about what to do to improve elementary science teachers' education. The process was not scientific, but rather was a humane, give-and-take process that resulted in agreed-upon principles for course improvement. The end product does not reflect the many hours of discussion that were required to reach consensus.

INITIAL ADVISORY COMMITTEE OUTCOMES

Prior to 1981, both students and faculty consistently reported that the term in which methods courses were offered was "heavy." The term consisted of a block of five, three-credit methods courses and a three-credit practicum. The practicum required a half day in the classroom.

Over the years, various concessions were made to accommodate a reasonable balance between methods course requirements and practicum experiences. The most visible accommodation was a reduction in the number of contact hours devoted to the 15 credits of methods courses. This reduction was justified on the basis that students experience a major component of methods experience in the accompanying practicum. In the case of science, this was not a valid assertion. Contact hours were reduced from 30 to 21 hours. However, students reported not being able to teach any science in their practicum due to peculiarities of classrooms to which they were assigned. There was a general feeling among students that they needed more science experience.

To compensate for perceived science contact hour deficiencies, the classroom time for the science course was then reexpanded to more nearly match that of an on-campus, three-credit course. Even with the increased time, students consistently indicated they wanted more time in science methods and evaluated the science methods course highly.

The Advisory Committee recommended that the science methods course be made prerequisite to the methods course block and that it be expanded from a three-credit to a five-credit course. It was decided that this would provide an intermediate step in classroom exposure prior to a half-day practicum and would satisfy the students' desire for more science. It would also alleviate the load pressure in Level III.

General national and state concerns (National Science Board, 1983; Milne, 1983; Daugs, 1983) about the science competencies of elementary teachers was discussed by the Advisory Committee at much length. Included in the discussions were the recommendations of the National Science Teachers Association (NSTA, 1983).

Early research (Beryyessa, 1959; Lamors, 1949; Lerrer, 1957; Rutledge, 1957; Wishart, 1961) revealed a positive correlation between science background and various teaching competencies. More recently, research indicates (De Rose, 1979; Fitch, 1979) that many elementary teachers feel unqualified to teach science because of their poor science content background.

Although there appears to be almost universal agreement that elementary school teachers should have a good science foundation, few colleges and universities have matched research findings with content offerings. Many science educators (Blosser, 1969; McDermott, 1976; Rowe, 1978; Suchman, 1976; Victory, 1974) also believe that process-oriented elementary teachers should be knowledgeable about the concepts and conceptual schemes that emerge as science inquiry progresses. Only one-third of the institutions surveyed by Stedman (1982) design their science content courses to meet the needs of elementary teachers. AAAS guidelines (AAAS, 1970) indicate that there should be a match between science topics that are taught to teachers and the science topics that are taught to children.

The Advisory Group recommended that the general education requirements for elementary teachers be revised to include Biology 101 (5 cr.), Chemistry 101 (5 cr.), Geology 101 (5 cr.), and Physics 120 (5 cr.). In addition, these courses should be modified to include all of the topics covered in the elementary science Utah Core Curriculum (1983).

They further recommended that the expansion of the science methods course from a three-credit course to a five-credit course include a major science, technology, and society component. This recommendation was based upon the summary of Piel (1981) and a general feeling that STS courses on a state and national level would influence the elementary curriculum of the future.

STUMBLING BLOCKS

The transition to the new program went amazingly smoothly. Departmental approval and acceptance involved discussion, but no conflict. The proposed changes were approved by the Council on Teacher Education after a written and 30-minute oral presentation. Students have questioned, but accepted, the content requirements. The only initial stumbling block was student advisory response.

All students in the elementary teacher program are assigned to a full-time advisor. For some reason, there was a tendency to be apologetic for the increased science requirements. As a result, many students avoided prerequisites, slipped by on the old program, or reflected the reservations of the advisors. It took about two years to remedy this situation, but the new program is now totally functional with the advising considered a major strength of the total program.

PLANNING METHODOLOGY

A Discrepancy Evaluation Model (DEM) was used in planning the overall design of the science methods course (Yavorsky, 1976). DEM design constitutes a structured description of the program, with information organized so that it can be used as an operational map of the program. The design includes: what is going to happen (activities--process), what should result if the activities are carried out (objectives--outcomes), and what is needed to carry out the activities (resources--input). Evaluation questions and sources of data categories were added to the basic DEM model.

In discrepancy evaluation, performance is compared to a standard. A program design serves as the formal representation of that standard and is to be stated in a form which makes standards readily subject to evaluation. If organized properly, the program design should facilitate clarification of program goals and facilitate the total planning process.

METHODS COURSE FRAMEWORK

The methods course is organized around ten basic components as illustrated in figure 1. In the section that follows, each component is outlined by program goal, topic, state objective, and an IPO framework. Each component is discussed at some length.

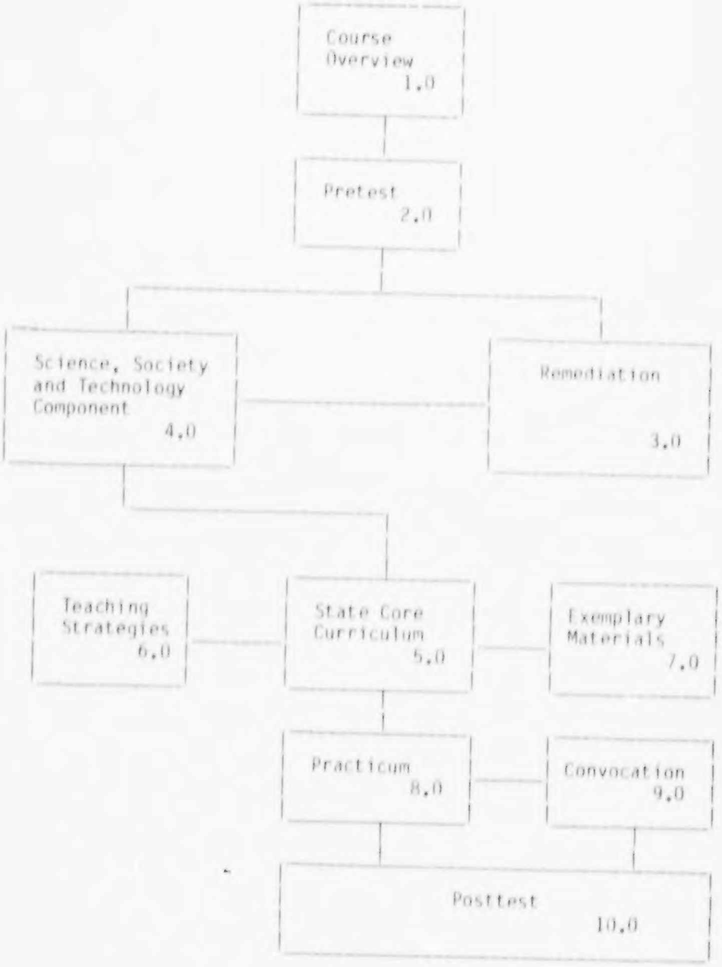
Course Overview 1.0
Pretest 2.0
Science, Society and Technology Component 4.0
Remediation 3.0
Teaching Strategies 6.0
State Core Curriculum 5.0
Exemplary Materials 7.0
Practicum 8.0
Convocation 9.0
Posttest 10.0

Figure 1. El Ed 401, Science Methods (5 credits) Component Flow Chart

Program goal 1.0 To provide an overview and outline of course requirements and procedures.

Topic 1.1 Course Outline

Objective: The student should be familiar with course components.

INPUTS	PROCESS	OUTPUTS
Students	The instructor provides a verbal and written description of the course.	Students will have an understanding of course goals, objectives, and procedures.
Printed course outline		
Classroom to seat 50	Time: 30 minutes	

EVALUATION QUESTIONS	SOURCES OF DATA
How well do students understand course requirements?	Course evaluation forms Instructor-student discussions

Topic 1.2 Requirements and Grading

Objectives: The student should be aware of course requirements and options for achieving them.

The student should understand grading procedures.

INPUTS	PROCESS	OUTPUTS
Students	The instructor provides a verbal and written explanation of course requirements and grading procedures.	Students will be aware of course requirements and options for achieving them.
Printed course requirements		
Instructor		Students will understand grading procedures for all components of the course.
	Time: 15 minutes	

EVALUATION QUESTIONS	SOURCES OF DATA
How well do students understand grading procedures & course requirements? Are students aware of options for achieving course requirements?	Course evaluation forms Instructor discussion and observation of student behavior Aid discussions with students

DISCUSSION

This component was designed to inform the student of course requirements and what was going to happen in the course. It was inferred from research findings that a high anxiety level generally accompanies poor student performance (Gandry & Spielberger, 1971). The general purpose of topics under Goal 1 is to alleviate anxiety by providing an understanding of what will be required in the course. Karzwell (1968) suggested that building student trust may reduce anxiety and promote better student teaching. Trust is increased when there is a common understanding of events and expectations. Therefore, it is desirable at the outset of the course that students be aware of what will be involved in the course.

McCaulley (1968) studied the distribution of the various learning "types" among students and teachers at various school levels. He found that there were three areas of preference:

1. Those who prefer to learn by direct immersion in activities, followed by a period of more abstract review.
2. Those who preferred to be given a picture of the place of the activity in the whole.
3. Those who preferred to go off in unexpected directions.

One of the major purposes of the course outline is to show that all three of the above options are a part of the course.

As the course was implemented, total time for this topic was increased to the levels stated above. Student course evaluations continue to rate both topic 1.1 and 1.2 highly. Instructors refer regularly to course components and IPOs during the term, reinforcing the initial exposure to the course outline.

The reward system, as demonstrated most openly by grades, is perhaps the greatest source of anxiety and greatest mediator of attitude. Evans (1976) concluded that grading does not fulfill its purported functions and can produce undesirable motivational effects. The negative effects of external rewards were well described by Deci (1975). Grading is particularly sensitive in the instance of the science methods course in that the grading philosophy of the course is not that of the department. College and departmental policy is that each course have as a grade goal an average GPA of 3.0.

Justification for alternatives to the externally imposed GPA goal of 3.0 is not easily documented. Simon and Bellanca (1965) reviewed grading practices. The basic issues revolve around normative concerns versus developmental concerns. If the research about cognitive development is taken into account, it can be concluded that grading practices based upon individual development, rather than those which judge students in comparison to one another, would be more appropriate. Students should be given the grade they earn.

It was considered important that the grading procedure be consistent with the philosophy of meeting individual needs through individualized curriculum. Mutual understanding of course goals, application of evaluation processes and instruments consistent with goals, and student/teacher discussion of grading policy should reduce some of the undesirable effects of grading (Robinson, 1979).

Grading is on a point system with a total of 290 points possible for the various course components. The basic grading philosophy is that all students should be able to attain the highest possible grade. Students should only be tested on things taught in the course. Participation, including attendance and tardiness, are part of the professional behavior and could be included as part of the final grade. Some components of the course are repeatable allowing full credit for those experiences. There is no target GPA for the course. However, the following general guidelines apply:

A - Clearly demonstrates excellence in all aspects of performance.

B - Good to excellent performance in nearly all aspects of the course requirements. Clearly above minimum performance.

C - The minimum level of performance acceptable for teaching in the elementary classroom. This does not carry the connotation of average, but rather acceptable performance in every respect.

D - Less than acceptable performance. A student operating at this level should take additional time to improve level of performance or drop.

F - Totally unacceptable performance.

Program Goal 2.0 To provide a means of determining student level of scientific literacy.

Topic 2.1 Content Assessment

Objective: The student will achieve a score of at least 80% in each of three (life science, earth science, and physical science) content area assessments.

INPUTS	PROCESS	OUTPUTS
Students Pretests	Students will be administered a paper and pencil pretest during a scheduled class time.	Identification of those students performing at less than 80% level.
Instructor	Time: 30 minutes	

EVALUATION QUESTIONS	SOURCES OF DATA
How well does the testing procedure operate? Has the pretest been validated? What is the reliability of the pretest? Are the prerequisite courses properly preparing the students?	Instructor feedback Course evaluations Validation process Test data Advisory Committee

Topic 2.2 Science Process Skills Assessment

Objective: The student will achieve a score of at least 80% on a comprehensive science process skill assessment.

INPUTS	PROCESS	OUTPUTS
Students Pretests	Students will be administered a paper and pencil pretest during a scheduled class time.	Identification of those students performing at less than the 80% level.
	Time: 35 minutes	

EVALUATION QUESTIONS	SOURCES OF DATA
How well does the testing procedure operate? Has the pretest been validated? What is the reliability of the pretest? Are the prerequisite courses properly preparing the students?	Instructor feedback Validation process Test data Advisory committee Student interviews

Program Goal 2.0 CONTINUED...

Topic 2.3 Science Attitude Assessment
Objective: The student will attain a score of at least 80% on an attitude toward science assessment.

INPUTS	PROCESS	OUTPUTS
Students Pretests	Students will be administered a paper and pencil pretest during a scheduled class time. Time: 10 minutes	Identification of those students performing at less than the 80% level.

EVALUATION QUESTIONS	SOURCES OF DATA
How well does the testing procedure operate? Does this component achieve desired goals?	Test data Student interviews

DISCUSSION

The original intent was that pretesting would be a computer-mediated process, with student testing done independent of class time. Though the pretests are now available for computer use, the approach has remained to administer the pretest as a group paper and pencil test during one of the early class sessions. Testing requires one hour and correcting and posting subscores requires an additional two hours of faculty time. Course evaluations have rated the present procedure highly.

The pretest was modeled after the British Columbia Science Assessment (Taylor, 1982). The pretest consists of five subparts: life, earth, and physical science content, science process skills, and attitude toward science. Validity considerations are covered in the 1982 British Columbia report. Content validity was determined by having approximately 175 elementary teachers, who had been trained as elementary science teacher-leaders, review potential items and eliminate any that they felt were not appropriate for elementary teachers. Test items were also compared with the standards and objectives stated in the Utah Core Curriculum (1987). All test items had comparable core components. Therefore, it was inferred that the pretest covered topics appropriate for Utah elementary teachers.

The 80% competency level on pretests was set arbitrarily. In all literature reviewed by Robinson (1979), the criterion of "minimum competency level" was, in the final analysis, arbitrary. The concept of minimum competency is in tune with Utah State Office of Education policy on Core Curriculum standards for all students. In correlating the preassessment with the State Elementary Science Core (1984), an attempt was made to realistically base all teacher competencies on a foundation of skills and knowledges found in the core. Thus, the minimum expectation for prospective teachers is that they have the performance level expected of their students. This approach rests on the assumption that minimal levels can be specified (Glass, 1976). Much controversy has existed over the issue of ability to measure competency levels. For the purpose of this course, performance levels are indicators based upon stated educational objectives.

The pretest was administered to methods course students over the past two years. These subjects included both students in a previous science methods course and in the present science methods course. Data from fall and winter terms, 1987, were used to identify faulty test items and to assess item effectiveness. A reliability coefficient was determined for the entire pretest by using scores from subjects that had been administered the pretest over a period of two years ($N=249$) using the Livingston criterion--referenced adjustment of Kuder-Richardson 20 with $KR20=.84$ and $R_{cr}=.87$.

Data were also collected on whether prerequisite science courses had been taken. Consistently, those who had not had the prerequisite science courses did not pass the comparable component of the pretest. At present, of those who do not pass a component of the pretest, about 10% have had the prerequisite course; of these, nearly all have received a grade of less than C, elected for pass/fail, or are transfer students who have not had a truly comparable course. The other 90% of those not passing the pretest have not had the prerequisite science courses. These students operate under the hope that a waiver policy allowing a challenge of the content course requirement can be achieved by passing the pretest.

No statistically significant correlation between the skills component of the test and the number of lab courses taken has been determined. Interviews revealed that many students had good lab experiences in high school.

The attitude toward the science section was designed to yield consistently high scores. The hidden assumption in the process was that if a student scores poorly on content or on skills and had a high attitude score, the person might be more willing to cope with remediation. Counseling sessions have tended to confirm this assumption. The high attitude scores tend to produce a sense of ability to cope with science.

Program Goal 3.0 To facilitate, in a variety of ways, remediation deficiencies identified in pretest procedures.

Topic 3.1 Content Deficiencies

Objective: The student who is below criterion level (80%) in any of the three content areas (life science, earth science, physical science) will:

A. Audit an existing course, or utilize a computer-mediated instruction program, or utilize a video-study guide, or arrange an individualized remedial program to improve competencies in the appropriate content area.
B. Retest until the 80% competency level is attained.

INPUTS	PROCESS	OUTPUTS
Students with content pretest scores of less than 80% Instructor Remediation resources	The student with deficiencies will elect one or more strategies to improve science content. Students must achieve 80% level of competency on a retest. Time: Variable	Student performance of at least 80% competency level in all science content areas.

EVALUATION QUESTIONS	SOURCES OF DATA
Do remediation procedures provide adequate content? Are remediation procedures reasonable with respect to time required? Are retests valid and reliable? What does the remediation process really do?	Student interviews Test scores Course evaluations

Topic 3.2 Science Process Skill Deficiencies

Objective: The student who is below criterion level (80%) on the science process skills subsection of the pretest will attend instructor-guided remediation sessions.

INPUTS	PROCESS	OUTPUTS
Students with process skill scores of less than 80% Instructor Lecture-Lab room	All students will participate in an instructor guided demonstration of science process skills. Students will also be provided self-study process skill guides.	Student performance of at 80% level of competency on midterm exam process skill test items.

Program Goal 3.0 CONTINUED...

Topic 3.2 CONTINUED...

INPUTS	PROCESS	OUTPUTS
Self-study guide Skill materials	Time: Variable	

EVALUATION QUESTIONS	SOURCES OF DATA
Do remediation procedures provide adequate exposure to science process skills? What is student response to remediation procedures? What does the remediation process really do?	Student interviews Test scores

Topic 3.3 Attitude Toward Science

Objective: The student who is below criterion level (80%) on the attitude subsection of the pretest will discuss, on a one-to-one basis with the instructor, possible implications of attitude toward science on future science teaching.

INPUTS	PROCESS	OUTPUTS
All students Instructor Test scores	All students meet with the instructor to discuss influence of attitude on science teaching. Where appropriate, the instructor and/or student will initiate remediation plans and procedures. Time: Variable	Students with a positive attitude toward science teaching. Some students may plan and carry out attitude improvement strategies

EVALUATION QUESTIONS	SOURCES OF DATA
Are remediation procedures achieving stated and hidden goals?	Student interviews

DISCUSSION

The remediation of deficiencies identified in pretesting was considered critical in progress in the course. The foundation of a common core of knowledge and skills was set as a prerequisite to progress in the course. Students not performing at acceptable levels on the preassessment must select and carry out appropriate remediation.

Work by Thompson (1980) and Kelley (1973) formed a basis for justifying an individualized component to the methods course. Mott (1980) summarized the merits of initial investments of development time to develop individualized programs as related to student performance and attitudes.

Consistent with the concept of individualization of the curriculum, alternative modes of remediation were developed. For each content area, these alternatives include:

1. Enroll in or audit existing courses;
2. Utilize a computer-mediated instructional program;
3. Arrange an individualized remedial program with a faculty member;
4. Propose some other alternative approach.

The primary responsibility for remediation rests with the student. The course instructor is a facilitator in the spirit of the "helping relationship."

In general, the approach to remediation has been judged acceptable. Although students with deficiencies have all elected to use the video-study guide approach to remediation, alternative approaches have also been retained as options. The remediation process does not give the student a profound background in a science content area, but does demonstrate student ability to learn the content required to teach elementary grade level science.

All but one student requiring remediation have completed the process in the term they were first registered for the course. This one person elected to take more time due to a pregnancy, but never did complete the remediation.

Remediated test items were written to match study guide content, but have not been validated.

Student interviews revealed that many students who had passed the pretests felt they were missing something. Thus, many students elected to view the remediation tapes on their own.

The process skills subtest revealed that many students scoring well on the pretest often could perform the skill, but did not know what the skill was. For example, they could classify objects but did not know that this process was called classifying. Because of this, all students were invited to attend the skills remediation sessions and all students were provided a skills study guide. This approach resulted in nearly 100% success on process skills items on the mid-term exam.

The combination of high performance on the pretest and very high performance on mid-term exams indicated that students had mastered science process skills at an acceptable level. Midterm and final exams are revised each term, so standardized test data will not be available.

The attitude subtest was designed to be a success-oriented component, the assumption being that if a student was told they had a good or excellent attitude toward science, the person would be more willing to cope with possible content or skills deficiencies. Interviews and counseling sessions have confirmed the above assumption.

The influence of science anxiety on attitude is an area that needs further research. It is felt that the methods course is doing a great job of alleviating these anxieties, but this has not been documented.

Final Form for Component 4.0

Program Goal 4.0 To provide a basic understanding of science-technology-society interactions.

Topic 4.1 Introduction to STS

Objectives: 1. The student will define, compare and contrast science, technology, and society.
2. The student will appreciate how science and technology contribute to new knowledge.

INPUTS	PROCESS	OUTPUTS
Students Classroom Video facilities Video: The Search for Solutions, "Situation" Instructor Handouts	A video presentation will be used in conjunction with handouts and discussion to introduce the concept of STS. Emphasis will be placed on how science and technology interact to produce new knowledge and new problems. Time: 1-1/2 hours	Students will be able to differentiate between science, technology, and society. Students will appreciate the role science and technology play in generating and solving problems.

EVALUATION QUESTIONS	SOURCES OF DATA
How well are course objectives being achieved? Do the procedures prepare students for components 4.2 and 4.3?	Test scores Course evaluations Student interviews

Topic 4.2 Impacts of Society

Objectives: 1. The student will examine past and present examples of the impact science and technology have had on society, economic growth, and the political process.
2. The student will infer broad perspectives on the interrelationships among science, technology, and society.

INPUTS	PROCESS	OUTPUTS
Students Classroom Video facilities Video: The Search for Solutions, "Information"	A video presentation will be used in conjunction with handouts and discussion to develop the concept of STS interactions.	Students will appreciate the impact of science and technology on society. Students will infer the need for a broad perspective when considering STS issues.

Program Goal 4.0 CONTINUED...

Topic 4.2 CONTINUED...

INPUTS	PROCESS	OUTPUTS
Instructor Handouts	Time: 1-1/2 hours	

EVALUATION QUESTIONS	SOURCES OF DATA
How well are course objectives being achieved? Do the procedures prepare students for Component #3?	Test scores Course evaluations Student interviews

Topic 4.3 Practical Applications

Objectives:
1. The student will examine STS issues that have personal relevance and that can be subjected to scientific inquiry.
2. The student will conduct an STS investigation.

INPUTS	PROCESS	OUTPUTS
Students Science faculty Various equipment	Students will work cooperatively in small groups with a science faculty person. Emphasis will be on solving STS-related problems, using the processes of science. Each student or group of students will carry out an STS investigation. Time: 9 hours	Students will have an increased STS awareness. Students will better relate STS issues to self. Students will conclude that STS issues lend themselves to scientific solution. Students will carry out a personal investigation.

EVALUATION QUESTIONS	SOURCES OF DATA
How well are course objectives being met? How effective is the use of science faculty to teach this component?	Test data Course evaluations Instructor interviews Advisory Committee

DISCUSSION

On the basis of course evaluations, it was concluded that students are adequately introduced to the concepts of STS in the first two sessions. Performance was more at the appreciation level than at a profound comprehension level. The videos used and assignments given provide a broad background and an introductory hands-on experience.

The real strength of the STS component lies in utilizing 4-5 science faculty as teachers for component 4.3. The class is divided into small groups and assigned to an outstanding scientist for about nine hours of interaction. During this time, each professor creates an STS-related science experience for the group. This experience gives the student exposure to the best of science, the best of science faculty, and an opportunity to experience first-hand a STS-related investigation.

The College of Science fully supports this concept and cooperating faculty, good for beyond the call of duty to serve the education students. This collaborative effort is one of the true highlights of the program.

Program 5.0 To provide background on the origin and requirements of the Utah Elementary Science Core.

Topic 5.1 Elementary Science Core Overview

Objective: The student will utilize the Utah Core Curriculum and the Elementary Science Resource Guide as examples of computer-managed curriculum.

INPUTS	PROCESS	OUTPUTS
Students Instructor Lab school principal State Science Core Elementary Science Computer facilities	The Utah Elementary Science Core will be introduced in a lecture-discussion session. This will then be tied to a computer-mediated curriculum resource which includes the Elementary Science Resource Guide. Time: 1-1/2 hours	Students will understand the relationships between the State Elementary Science Core and the Elementary Science Resource Guide. Students will utilize a computer-managed curriculum process to obtain science teaching resources.

EVALUATION QUESTIONS	SOURCES OF DATA
Are students able to use the technology? Does the process adequately introduce the Utah Core Curriculum and the Elementary Science Resource Guide? Do students use the resources on their own? How well does the process relate to the Edith Bowen Lab School Project TINMAN objectives?	Course evaluations Test data Student interviews Lab school principal interviews

DISCUSSION

Classroom experiences in the science methods course are organized to familiarize the student with a variety of curriculum components, including the Utah Core Curriculum, hierarchial arrangement of standards and objectives, computer-mediated curriculum management, science lesson plans, textbook correlation, integration of the total elementary curriculum extensions, and gifted and talented applications. The Utah State Core consists of a set of standards and objectives, arranged by grade level. This framework has been keyed to a numbering system and expanded into a computer-mediated curriculum retrieval system called the Utah Elementary Science Resources Guide.

There is no research justification for inclusion of the Guide in the new methods course. The decision was pragmatic in that it was thought that the guide would be a good introduction to computer-managed curriculum and would serve as an introduction to the Utah Core Curriculum.

The Utah Elementary Science Resource Guide consists of curriculum materials organized in a prescribed format and available on Apple II compatible diskettes. The resources are all keyed to Utah Elementary Science Core standards and objectives. For each standard and objective, the guide supplies the following:

1. a statement of the standard and objective;
2. appropriate vocabulary keyed to World Book Encyclopedia to give content background for the teacher and/or subject;
3. one or more basic lesson plans that can be used by the teacher to achieve the stated objective;
4. a listing of a variety of textbook sources that treat the same topic;
5. suggestions for correlation with the rest of the curriculum, e.g. ties to math, reading, and language arts;
6. suggestions for extensions and gifted and talented activities.

This component was an innovative success. Student response has been very positive, as evidenced by course evaluations, and student performance on related exam items has been excellent.

The component is now team taught by the Edith Bowen Lab School principal and the course instructor. The inclusion of the principal was made to provide an introduction to Project TINMAN, a computer-mediated curriculum management system utilized in the lab school in which methods course students do their practicum. The inclusion of the total management system expanded the original intent of using the computer as a resource for science curriculum materials to a more relevant total picture.

The use of computer-mediated videodisc was also added to the presentation.

Over half the students reported using the above described resource during their practicum. No student has reported negative feelings about this component.

Program Goal 6.0 To apply teaching principles, skills, and methods to teaching elementary science.

Topic 6.1 Scientific Literacy

Objectives: The student will define scientific literacy, apply the concept to classroom situations, and identify or devise means of assessing student levels of scientific literacy.

INPUTS	PROCESS	OUTPUTS
Students Instructor Various curriculum materials Test item development handout	The concept of scientific literacy will be introduced in a lecture-discussion session. Various curriculum materials and handouts will be used to assist in developing assessment items. Time: 1-1/2 hours	Students will define scientific literacy. Students will recognize examples of lessons that develop comprehensive application and attitude components of scientific literacy. Students will identify and devise assessment items that measure the components of scientific literacy.

EVALUATION QUESTIONS	SOURCES OF DATA
How well do students achieve objectives? Does the process, as defined, match what happens in the classroom?	Course evaluations Test data Interviews

Topic 6.2 Historical Perspective

Objective: The student will demonstrate a basic understanding of the development and characteristics of elementary science curricula over time.

INPUTS	PROCESS	OUTPUTS
Students Instructor Samples of: Health Science, Silver Burdette PLT, SCIS, ESS, ESSP.	The instructor will provide historical background on the evolution of elementary science curricula. Sample materials illustrating various approaches to teaching elementary science will be made available. Time: 1-1/2 hours	The student will identify and describe examples of four generations of elementary science curricula The student will identify strengths and weaknesses of various elementary science curricula.

EVALUATION QUESTIONS	SOURCES OF DATA
How well do students achieve the objectives?	Midterm and final exams.

Program Goal 6.0 CONTINUED...

Topic 6.3 Multidisciplinary

Objective: The student will investigate potential for integrating elementary science with the total elementary curriculum.

INPUTS	PROCESS	OUTPUTS
Students Instructor	The instructor will model a number of examples of tying science to other parts of the curriculum.	Students will relate science objectives to other subject areas.
Elementary Science Resource Guide ESSP	Resources will be shared that exemplify integration of science with other subject areas.	Students will apply principles learned in this component to practicum and/or convocation experiences.
PLT, PW	Time: 1-1/2 hours	

EVALUATION QUESTIONS	SOURCES OF DATA
How well do students achieve objectives? Are there any problems in the delivery system? Does the process as stated match what happens in the classroom?	Test data Course evaluation

Program Goal 6.0 CONTINUED...

Topic 6.4 Laboratory Techniques and Equipment

Objective: The student will demonstrate familiarity with laboratory equipment and supplies commonly used in elementary science programs. The student should be aware of hazards and safety precautions associated with elementary science laboratory work.

INPUTS	PROCESS	OUTPUTS
Students Instructor Lab safety manual School Science Safety Station Studies/ equipment	Students will follow self-instructional procedures to familiarize themselves with common elementary science equipment, supplies, and safety procedures.	Students will identify, describe, and appropriately use common elementary science equipment and supplies. Students should be aware of hazards and safety precautions associated with elementary science laboratory work.

EVALUATION QUESTIONS	SOURCE OF DATA
How well do students achieve objectives? Are there deficiencies in either inputs or processes?	Test data Course written assignments Course evaluations Interviews Advisory Committee NSTA-Elementary Committee

DISCUSSION

The substance of component 6.0 is what is found in most traditional elementary science methods courses. Scientific literacy is covered in detail, along with a historical perspective. Students are comfortable with the lectures and respond well to test items that relate to components 6.1 and 6.2.

Program Goal 6.2 reflects a philosophy that promotes teaching elementary science as an integrated part of the total elementary curriculum. Historically, the elementary science curricula of the 1960's were good science and were taught as science for science's sake. A tendency, first established by the Lippincott Elementary School Science Program and the Modular Activities in Programmed science, to teach science in a multidisciplinary mode, is now reflected in many programs. Based on evidence from students that indicated science experiences enhance cognitive skill development and have positive effects on language arts skill development, Mishler (1982) recommended that science and language arts be integrated. Wellman (1978) reviewed educational research and demonstrated a clear and positive relationship between science and language arts.

E. H. Moose (1903) long ago suggested that science and math be integrated "so that always students' mathematics should be directly connected with matters of thoroughly concrete character..."

It has been demonstrated by Almy (1970), Renner (1971), and Stafford (1969) that a child's level of thought influences achievement in mathematics. It can be inferred from these studies that there is at least an indirect relationship between science and mathematics.

Science can also promote creativity. Torrence (1962) included hypothesis forming as a part of creative thinking. Children involved in science activities also develop a reservoir of experiences that can be tapped through creative writing.

Much research has been reported on transfer of training related to the topic of integration of science with other disciplines (Thorndike & Woodworth, 1901; Judd, 1939; Bayles, 1960; Gagne, 1962; Cranback, 1963; and Orata, 1941). Kern (1979) indicates there are three ways to integrate curriculum. The approach followed in the science methods course is what Kern terms a "fused curriculum in which the areas are taught as one."

Research indicates that experience-based elementary science programs foster development of language and reading skills (Barufaldi and Swift, 1977). Wellman (1978) conducted research that indicates that elementary science instruction can increase achievement scores in reading and language arts, and can also offer alternative teaching strategies to motivate children with difficulties in these areas. In another study, Wellman also found evidence that science instruction improves reading skills in grades 4, 5, and 6:

Some of the benefits that intermediate-grade children have been found to derive from science instruction are: vocabulary enrichment, increased verbal fluency, enhanced ability to think logically, and improved concept formation and communication skills.

The hazards and safety precautions section of component 6.4 was a success. Students used a study guide and a lab safety manual to self-instruct with respect of the objective. The required written assignment and test results confirmed that students understood the basics of lab safety. No changes occurred in this component over the three 1986-87 terms.

Familiarity with laboratory equipment and materials commonly used in elementary classrooms was not achieved. It was assumed that this background would have been achieved in the four foundation science courses and that a brief review would suffice at this point. At this point, both the foundation courses and methods course component 6.4 are being revised to determine how best to familiarize students with appropriate lab materials and equipment.

Program Goal 7.0 To familiarize students with exemplary elementary science curricula.

Topic 7.1 Industry and Non-profit Organization Curricula

Objective: The student will describe the major feature of a variety of third generation curricula.

INPUTS	PROCESS	OUTPUTS
Students Instructor Evaluation forms Curriculum Materials *Project Wild* *Project Learning Tree* *Water Education K-6* *Energy and Man's Environment* Resource persons Workshop materials Project presentor	Materials will be shared in a variety of formats, ranging from brief (1 hr.) classroom presentations to full day (6 hr.) workshops. Project resource people will assist the instructor in the full-day workshops.	Students will identify desirable and undesirable features of industry or non-profit organization produced materials.

Time: Variable

EVALUATION QUESTIONS	SOURCES OF DATA
How well do students achieve the objectives? Does the process facilitate ease in achieving course objectives? How well do students respond to optional Saturday sessions?	Test scores Course evaluations Student interviews

Program 7.0 CONTINUED...

Topic 7.2 Publisher-Produced Curricula

Objective: The student will be able to describe the major features of two publisher produced K-6 elementary science curricula.

INPUTS	PROCESS	OUTPUTS
Students Instructor Classroom sets of two textbook series Study guide	Students will evaluate two textbook approaches to teaching elementary science. One examination will be a self-study approach and the other will be an instructor lecture demonstration. Time: 4 hours	Students will describe the desirable and undesirable aspects of two publisher-produced elementary science textbooks.

EVALUATION QUESTIONS	SOURCES OF DATA
How well do students achieve the objectives? Does the process facilitate familiarity with elementary science curricula?	Test scores Course evaluations Student interviews

Topic 7.3 Supplementary Materials and Journals

Objective: The student will be familiar with resources found in *Science and Children* and *Science Scope*.

INPUTS	PROCESS	OUTPUTS
Students Instructor *Science and Children*, *Science Scope* Handout	The instructor will introduce and share sample activities from NSTA publications. Students will complete an assignment related to one of the shared publications.	Students will identify Science and Children and Science Scope as NSTA publications. Students will be aware of materials available from NSTA.

EVALUATION QUESTIONS	SOURCES OF DATA
How well do students achieve the objectives? Does the process facilitate objectives?	Test scores Course evaluations Student interviews

DISCUSSION

Traditionally, much science methods course time has been devoted to familiarizing students with curriculum materials. However, review of the literature on science methods course research reveals little or no evidence on how to best incorporate curriculum material into a methods course. Gremli (1985) probably identifies the most realistic variable that precludes in-depth exposure to curriculum materials, that being the reality of the classroom. Given such findings, and the intuitive feeling that all existing curricula cannot be covered in any in-depth way, the approach in the science methods course will be to broadly familiarize students with a variety of curriculum material, but not immerse them in any one program.

This component of the course was well received by students. Course evaluation feedback was very positive and performance on related exam items was consistently high. A real plus for this component was provision of free materials: Project Learning Tree, Project Wild, Water Education K-6, and Energy and Man's Environment, for all students. Presentations have ranged from short in-class sessions to full days. Full days were billed as optional Saturday experiences with five points extra credit given for attendance. This approach has been outstanding in that consistently 2/3 or more of the students attended the full-day sessions, adding 18 voluntary contact hours for many students. This approach will continue to be followed in the future.

The most interesting aspect of component 7.2 was that students entered the session with a negative attitude toward textbook use in elementary science classrooms, but exited the experience with just the reverse attitude. The change was attributed to instructor attitude and the quality of the text series examined. However, most students use a hands-on, no-textbook approach in their practicum.

The exposure to publications such as Science and Children has evolved considerably. The approach of lecture demonstration, use of sample materials, and an assigned activity provides students with exposure that is retained at least until final exam time.

Program Goal 8.0 To provide the opportunity for students to teach a series of science lessons in an elementary or middle education classroom.

Topic 8.1 Practicum

Objective: The student will work with a cooperating classroom teacher to plan, teach, and evaluate an elementary science teaching experience.

INPUTS	PROCESS	OUTPUTS
Students	This component is designed to give the student an opportunity to teach science lessons in an elementary classroom.	Students should demonstrate professionalism in dealing with cooperating teachers, principals, and students.
Cooperating teachers		
Lab School facilities	The classroom teaching will be done in an Edith Bowen Lab School classroom as part of the Level III practicum.	Students should demonstrate ability to plan effectively.
		Students should teach three or more science lessons.

EVALUATION QUESTIONS	SOURCES OF DATA
Are students adequately prepared to teach science in their practicum?	Cooperating teachers Level III Evaluations Edith Bowen School Faculty

DISCUSSION

The merits of actual classroom practicum experiences are widely documented (Repicky, 1977; Weaver, 1979; Sunal, 1978; Harty, 1984).

The practicum for the science methods course occurs during the methods block practicum in Edith Bowen Laboratory School. A pass/fail grade is assigned by cooperating teachers for half-day practicum experiences that extend over an entire term. Students must teach some science during that time period.

Program Goal 9.0 To provide a culminating experience where students can demonstrate teaching competencies.

Topic 9.1 Convocation

Objective: The student will plan and conduct a special science learning experience for a group of children.

INPUTS	PROCESS	OUTPUTS
Students Instructor Cooperating Elementary Schools Various resources	This component provides the student with an opportunity to demonstrate mastery of science content and teaching. Each term, a special topic or topics are selected for development. Students review aspects of scientific literacy, teaching skills, and assessment. Small groups or individuals plan special learning experiences that are carried out in elementary classrooms as part of a convocation day. Format and topic vary from term to term. Time: 8 hours	Students should demonstrate ability to work with a variety of people. Students should be able to plan effectively. Students should make appropriate space, equipment, and people arrangements. Students should conduct the convocation in a professional manner.

EVALUATION QUESTIONS	SOURCES OF DATA
How valuable is an additional classroom or teaching experience? Is the concept of a convocation viable? How do elementary children respond? How do classroom teachers respond?	Course evaluations Student interviews Teacher feedback

DISCUSSION

The concept of a convocation as a culminating experience was a product of experience with science fairs and exposure to the "convocations" approach used in the Albuquerque public schools.

The convocations consist of a series of special sessions for elementary grade level students. Emphasis is on Type II and Type III Reuzuli Triad (Renzuli, 1977) science experiences, designed primarily to reduce the gap between existing achievement and the real potential of all students.

In planning the convocation, a student should consider four factors (Schwab, 1973). These are: teacher, learner, curriculum, and milieu. It is the teacher's obligation to set the agenda and decide what concepts and events contribute to a learning experience. Gowin (1981) uses the term governance rather than milieu to describe factors that control the meaning of a learning experience.

This component was originally designed as an optional experience. However, it has turned out to be one of the highlights of the course. As such, it is concluded that it should be a required component.

Format for the convocation varies from term to term. Basic ingredients included: a science topic, lots of planning, and a full day of teaching science in an elementary school. The component was a practical way for students to demonstrate mastery of content, materials, and teaching skills. Course evaluations are very high for the component and teacher response in the schools visited was very favorable.

Program Goal 10.0 To provide a means of measuring growth and exitlevel of performance.

Topic 10.1 Posttest

Objective: The student will demonstrate mastery of course objectives in accordance with prescribed (80%) criteria levels.

INPUTS	PROCESS	OUTPUTS
Students Midterm exam	Testing will cover all major aspects of the course. Grading is set up so that students performing at less than the 80% level of competency on exams will obtain less than a passing grade for the course.	Students will demonstrate test performance at the 80% or better level.

EVALUATION QUESTIONS	SOURCES OF DATA
How well do students achieve course objectives? Do tests measure course objectives? How do students respond to testing?	Test scores Course evaluations

DISCUSSION

Student performance on midterm and final exams was outstanding. Grade distributions were consistently higher than college averages. Student course evaluation data indicated a general approval of tests and a feeling that tests matched objectives and course expectations.

No effort has been made to standardize the exams. Validation and reliability data are not available on these tests.

SO WHAT?

The bottom line is that students who graduate from the program are very employable. They have a science background that puts them far ahead of many teachers in the field. As first year teachers, they have survival skills that past graduates may not have had. Computers and related technology are not a threat.

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CHAPTER 5

Strengthening the Preservice Formation of Secondary Science Teachers Inside-out not Outside-in

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The Challenge

Making science user-friendly is a challenge worthy of our best efforts. Science affects everyone's lives in ways which require people to be intelligent consumers of science in their daily decision-making. If one has experienced science in user-friendly encounters, then it is likely that science will be meaningfully involved in our decision-making processes, both in professional and personal applications.

Common sense, vast personal experience, and contemporary research all suggest that a user-friendly event is one which alerts the learner through language that is comprehended, carries the learner through new experiences, delivers the learner at a higher level of understanding, and enables the learner to make applications--put the ideas into action. A user-friendly event then assumes first that there is a teacher skilled in the craft of teaching. A skilled teacher is one who is understood to be knowledgeable in science, in problem-solving, in pedagogy, and especially in interpersonal skills.

A Rationale for the Skilled Teacher

A skilled teacher for the secondary science classroom is one who is developed rather than trained. This formation of a science teacher is a strategy which is, in reality, the product of combining the essential elements of four research areas--the content of science, problem solving, environmental essentials, and personal involvement.

A. The Science Conceptual Base

From a broad base of both scientific discoveries and accumulated knowledge, we have a vast storehouse or menu of information about our natural world. Embedded in this information are strategies by which scientists have searched to understand the workings of our physical and biological world. But science is more than information; science is more than the strategies of searching. Science gives us the ability to know when to combine what is known with searching strategies to generate creative insights or to solve problems (Bybee, 1976; Wavering, 1980).

B. The Problem Solving Base

Through cognitive science research, we possess many helpful bits of knowledge to explain how people solve problems (Rutherford, 1980). That research suggests that we solve problems best when we are confronted with an incomplete or unsolved event about which we know enough to ask informed questions (Winne & Mack, 1977; Anderson & Smith, 1981). Given an array of searching strategies to back up our questions, we can move toward problem resolution if given an adequate context for exploration, data collection, and interpretation (Norton & Butts, 1973).

C. The Environmental Context Base

In a widely documented set of studies of effective schooling, Blum (1984) has described what happens when students are performing in school settings in which we would not expect them to be successful. Students are academically successful in these settings when by most criteria they otherwise have had little access to success. Based on the findings of these studies, schooling is user-friendly (and by implication so might science be) if the four groups which function in the schooling context work together. These groups are comprised of the students, teachers, administrators, and parents (Blum, 1984). Optimally these four groups work together in a specified direction. It is critical to note that in places where schooling is not user-friendly, at least one of these groups is absent or is not involved (Ralph & Fennesy, 1983).

Likewise, effective schools are characterized by four unifying concepts. Schools are more effective if they are characterized by (1) a common agreement concerning the goals of schooling (Squires, 1980; Bickel, 1983; Alexander & Pallas, 1984), (2) a supportive climate for those goals (Clark, Lotto & McCarty, 1980; Squires, 1980; Eubanks & Levine, 1983), (3) the instruction to facilitate those goals (Squires, 1980; Anderson, 1982; Eubanks & Levine, 1983; Alexander & Pallas, 1984), and (4) the monitoring of individual progress toward those goals (Squires, 1980; Eubanks & Levine, 1983; Bickel, 1983).

As described in these research studies, schooling (and also science) is user-friendly to the extent that all four groups (students, teachers, administrators, and parents) perceive academic learning to be the primary and most important reason for the schools. Further, schooling is seen as a way to help the student achieve success, and this success is a commonly held expectation for everyone. Everyone accepts that schools are places for learning. But learning must be mastered by the student, and experience alone is not sufficient for learning to occur.

A second direction or factor for the model of user-friendly science is a school climate which supports academics or science learning. The school administrator plays a key role as one who must understand and accept academic learning as the purpose for schooling. The effective administrator spends time in the school halls, classrooms, and laboratories demonstrating more care about student academic success than personal popularity. The administrator sets consistently high standards of expectation for the school with schooling routines that are consistently and fairly enforced. Effective administrators are guided by the conviction that personal actions do make a difference, especially in actual attendance in class.

A third factor in the user-friendly science model is classroom instruction. Science is user-friendly to the extent that classroom experiences are planned in advance and articulated with clear linkages between goals, activities, and tests. These classes are taught by teachers who are "on-task" and who maintain extensive contact with their students. Classroom experiences are also regularly extended through relevant homework assignments.

The fourth factor, personal monitoring of progress, is also an essential component of the user-friendly science model. This monitoring must be clearly related to goals, frequent in occurrence, and reflective of the fact that schools care about the individual and about the personal responsibility of the student to participate in the process.

D. The Personal Involvement Base

The Fuller Concerns Model (Fuller, Pilgrim & Freeland, 1967) provides another research base to help us expand our rationale for the skilled teacher. In her pioneering work, Fuller described a series of stages of concern that each of us faces when presented with a new challenge. We first experience the ME level: Can we survive or do we understand enough about the language to function? When we have resolved this stage, we are ready for the THEM or IT stage. Here we are concerned about what they or it is like, or what more we can find out about the event. Only when we are comfortable with our personal survival and our knowledge of the event are we then able to move on to the ME/THEM issues or more mature concerns of how we can help others or make the event happen again.

From scientific research, we have the content of science. Cognitive sciences research provides us with knowledge of how to learn or solve problems, especially as they are found in the classroom context. The research on effective schooling gives us knowledge of who and in what directions we must link together for success in the classroom. To be truly user-friendly, we must begin with people, the prospective teachers and their concerns or their readiness to learn. So we come back to the initial assumption from which we began: In the formation of a science teacher, we must pick up individuals first before we can carry them and deliver them at a stage where they can be effective in the classroom.

A Program for Developing Secondary Science Teachers

The general philosophy of formation of science teachers of this chapter is that excellence in science teaching is the outcome of opportunities for teachers to become committed to teaching, confident in their science knowledge, and competent in their ability to manage both ideas and people. These four goals can be accomplished in a developmental program using experiences in schools to help the individual form personal skills and competencies. Being a teacher is thus an "inside-out" phenomenon rather than an external "outside-in" training routine.

Science teachers must be competent in their teaching field. This competence may be accomplished by their coming to the program with a completed content major in science. On our campus this major requires that they have at least 40 quarter hours in one science area and at least 15 quarter hours in two of three other areas, plus 20 hours of mathematics. Building on this content base, there are four phases in the plan for the formation of secondary science teachers.

In Phase I, the prospective teachers have a variety of experiences on campus and in-school opportunities to explore what being a teacher means in addition to examining their own personal commitment to teaching as a career. A variation of this phase which is useful in some situations is to have the prospective teacher serve as a paraprofessional staff member in a school while taking this first phase course. A further strengthening of the tie between school experiences and personal commitment is to have the course taught on the school campus rather than at the college setting.

Phase II enables the participant to move into practicing organizing ideas for instruction--the management of ideas and practice in organizing pupils or people management. In this practice phase, the task is defined and a variety of options are practiced in on-campus and in-school field experiences in middle and high school science classrooms.

Phase III is the full-time student teaching quarter. From their initial observing and tutorial roles, the preservice teachers assume full responsibility for planning and managing the teacher's daily responsibilities.

Phase IV consists of the first two years induction into teaching. There is a critical need for continued support for the teachers newly appointed on their first job. This time is generally characterized by isolation when support is needed but, unfortunately, conventionally absent. In this induction phase, the teacher has access to a monthly consultation in the classroom by a team of experienced teachers, monthly dialog sessions with other new teachers and the district's commitment for them to participate in state and regional professional meetings of such state and national organizations as the National Science Teachers Association.

Summary

Conventional courses for prospective secondary science teachers tend to be isolated vignettes of how to plan and conduct science classes. Presented here has been a plan for strengthening the preparation of secondary science teachers by focusing on helping them develop as individuals.

The basic theme of this plan for the formation of science teachers is that excellence in science teaching is the outcome of opportunities for the teachers to be committed to teaching, confident in their science knowledge and competent in their ability to manage both ideas and people. To assist prospective teachers in acquiring these goals, a four phase program provides for the following:

time to make a personal commitment to teaching,
    time to practice with teaching skills,
        time to practice in the classroom, and
            time to experience induction into the teaching
            profession during their first two years on the job.

The success of the program for the formation of science teachers is seen in the extent to which it has demonstrated that prospective teachers are successfully becoming part of the community of science teachers.

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CHAPTER 6

The Continuing Education of Science Teachers - An Essential Ingredient in Educational Reform

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Four years and scores of reports have resulted in numerous recommendations and reforms aimed at improving science education. In one sense the recent reforms resemble efforts undertaken in 1950 with the National Science Foundation's 20 year investment in curriculum development - reform was then and is now conceptualized and implemented in the all too familiar "top-down" approach to change. Prestigious national commissions have studied education; state houses have legislated reforms; teachers have been charged with the responsibility of compliance. Unfortunately, in the wisdom of Megatrends (Naisbitt, 1982) "Trends are bottom-up, fads top-down" (p. 3). Reforms may have little impact on the outcomes of education without grass-roots programs aimed at supporting and improving the everyday instructional activities of teachers.

In other ways current reform efforts are quite different. Economic security rather than national defense fuels reform in the 1980's. Success in the classroom, particularly in science and mathematics classrooms, is seen to hold the key to gaining an economic edge in the international marketplace, although there are no data to suggest that science education actually increases economic productivity (Champagne & Hornig, 1987, p. 11). The challenge for science educators at all levels is not only to improve the quality of science learning for students who are interested in science but to broaden the base of knowledge, skill, and appreciation of science to include students who heretofore have been neglected. No longer will it be sufficient to develop scientific and technologic literacy among the 2% of the population who will become decision makers and policy leaders and the 18% of the attentive public (Miller, 1983). Whether students' future career aspirations are to enter a scientific field of study or to join the ranks of the service sector, science and technology will occupy a central role in their everyday activities. At the present time, for example, service industries account for 71% of the gross national product and 75% of all jobs and are projected to continue growing (Quinn, Baruch, & Paquette, 1987). The new service industries are defined "...to include all economic activities whose output is not a physical product or construction, is generally consumed at the time it is produced and provides added value in forms...that are essentially intangible concerns of its first purchaser" (Quinn, Baruch, & Paquette, 1987, p. 50). These new service industries are driven by advanced technology and will require highly skilled, scientifically and technologically literate workers to sustain their growth.

To attract and develop science teachers capable of bringing about high level learning in and appreciation for science among all students, grades K-12, presents formidable challenges to higher education. Even more difficult than the challenge of reforming preservice science teacher preparation may be the task of nurturing the continued development of science teachers once they enter the profession. Higher education is well suited to provide for the continuing education of science teachers - the key to long term improvement in the quality of science teaching and learning.

This chapter documents the need for institutions of higher education, and particularly centers of science education, to take an active, leading role in planning continuing education programs for science teachers. Background information is first presented, comparing the impetus for reform in science education in the 1950's with that in the 1980's. Science education in Japan is then examined with attention focused on what lessons might be learned from the Japanese regarding classroom instruction and the continuing education of science teachers. Next examined are the recent reforms recommended for improving the quality science education programs for students and teachers. The chapter concludes with the identification and discussion of five major areas in which centers of science education can make important contributions to the continuing education of science teachers.

Background

Government interest in scientific research, manpower, and education for peacetime uses was initiated in 1944 with President Franklin Roosevelt's letter to Dr. Vannevar bush, then the Director of the Office of Scientific Research and Development, the agency directly responsible for coordinating the nation's scientific and technologic efforts during World War II. In his letter, President Roosevelt sought Dr. Bush's recommendations for peacetime efforts related to continued research and development in science and specifically asked whether an effective program could be developed for discovering and developing scientific talent in American youth (Bush, 1960). The results of Bush's efforts led to the eventual formation of the National Science Foundation.

Precollege science education has been the stepchild of the National Science Foundation since its formation. Originally, NSF's functions were limited to the support of science activities at the undergraduate and graduate school levels. With passage of Public Law 92-372 in 1972, the NSF was charged with the responsibility of initiating and supporting basic scientific research and programs to strengthen the nation's scientific research potential and science education at all levels (Crane, 1976). The foundation has had a history of reluctance to become involved in precollege science education.

With the end of World War II industry would not wait for government to respond to the need for improved programs in science education. Major science and engineering businesses realized their dependence upon a continuing supply of highly trained scientists and engineers and identified high school as the weak link in the educational ladder. Businesses turned to higher education for help. General Electric convened the first summer institute for science teachers, who were designated by the company as GE Science Fellows. The six week program consisted of graduate courses in modern physics, electronics, and applications of physical measurements and was offered at Union College in Schenectady, New York in the summer, 1945. Four years later the Westinghouse Educational Foundation Program brought science teachers to the campus of the Massachusetts Institute of Technology for a six week, indepth study of science and engineering. From the beginning, summer institutes proved popular among science teachers.

The Foundation's first venture into science education was limited to the improvement of instruction at the college level. J. W. Buchta proposed to the Foundation two summer institutes in physics, one for college instructors and one for high school teachers, with overlapping sessions. The college program was funded by the NSF for the Summer, 1953; the high school program, although denied funding by the NSF, was later supported by a grant from the Ford Foundation and held at the University of Minnesota, as was the college program (Crane, 1976).

The impetus for NSF involvement in precollege science education came not from within the Foundation but from President Eisenhower who had heard of the growth of Soviet scientific manpower. Funding for the Foundation's Education in the Sciences Program was increased from $160,789 in 1954 to $315,790 in 1955. From humble beginnings consisting of four summer institutes offered to college teachers in 1954, the increased funds made it possible to offer eleven summer institutes in 1955, six for high school teachers and five for college teachers. When all available evidence later pointed to the need to improve precollege science textbooks and the nation harbored fears of technological inferiority fueled by the successful launch of Sputnik by the Soviet Union in 1957, the NSF entered the business of curriculum development, enlisting the support and service of leading scientists. NSF funding for curriculum development and teacher education peaked in 1968 at approximately $13 million. By 1976 funding for curriculum development had dropped to $5.5 million, support mainly to continue projects already started. As a result of the NSF's support for science curriculum development alternatives to traditional science textbooks were made available, science content was updated, and interest in science improved, although mainly among students in elementary rather than secondary grades (Welch, 1979). With needs for scientific manpower fulfilled, changing national priorities, claims of promoting a national curriculum, and dwindling popular support for what were perceived to be curricula that promoted non-traditional societal values, the NSF terminated its 20 year experiment in curriculum development amid cries for a return to the basics.

Thirty years have elapsed since the launching of Sputnik propelled curriculum development in science into the national limelight. The United States once again faces a crisis in science and mathematics education brought about by an increase in national debt, an imbalance in international trade, and the realization that other nations, particularly Japan and Korea, have surpassed the US in many areas of manufacturing and trade (Jennings, 1987).

The world economy has undergone a profound transformation. Manufacturers of electronic appliances in the United States long ago recognized and complained that the Japanese could undercut US prices because of low-cost labor. Businesses adjusted to this economic reality by contracting with low-cost producers in Japan for parts and finished products, content to be producers of knowledge while Japan manufactured parts and finished products. In time the cost of Japanese labor increased and Japanese manufacturers turned to Korea, where workers put in a twelve hour day, seven days a week for about $3,000 a year. Now the Japanese compete with the United States in the knowledge production business; Korea is soon to follow. To stem the flow of capital and jobs to Japan and Korea, the United States need not sacrifice the standard of living for its workers. To maintain a high-wage level society the US economy must be based on wide scale use of very highly skilled workers, backed up by the most advanced technologies available (Carnegie Forum on Education and the Economy, 1986).

Comparative studies of the US and Japanese economies and business practices have identified education as the major factor responsible for Japan's success in the world marketplace. The Japanese, according to the reports, do a far better job of educating all students at a level far higher than that in the United States (Jennings, 1987).

The Competition

The success of Japanese students in the world educational arena has been convincingly demonstrated on two successive international studies of school achievement in science and mathematics. In 1970, the educational achievement of 10-, 14-, and 18-year-olds in nineteen countries was examined in a study conducted by the International Association for the Evaluation of Educational Achievement (Comber & Keeves, 1973). Japanese students, ages 10 and 14, ranked first among all nations on science knowledge-testing knowledge of biology, chemistry, earth science, and physics (The Japanese did not test 18-year-olds on knowledge of science). Results of the Second International Science Study completed in 1983 and 1986 (with different levels of students in each administration) revealed Japanese students once again outperformed their American counterparts-advanced, regular, or non-science students (Rothman, 1987).

Japan and the United States agreed in 1983 when President Reagan and Prime Minister Nakasone met to undertake a cooperative study of education in each other's country. The studies were sponsored by the United States-Japan Conference on Cultural and Educational Interchange (CULCON). Chester E. Finn, Assistant Secretary of Education, and C. Ronald Kimberling, Assistant Secretary for Postsecondary Education, were responsible for the US study of Japanese education, and the Japanese Ministry of Education, Science, and Culture assumed responsibility for carrying out Japan's study of American education. Japanese Education Today (Leestma, August, George, & Leek, 1987) reports the findings of the US study, and Educational Reform in the United States (Japanese Study Group, 1987) presents the findings of the Japanese study group. The Japanese examination of US education was undertaken at a time when pressures were mounting at home to reduce the rigidity and structure of education.

The Japanese report on education in the United States presents an overview of the reforms in secondary education, describes the interface between secondary and higher education, and examines reform in undergraduate education. Noticeably absent from the Japanese report is any mention of reform in elementary school education, targeted recently in all the major reform reports as a critical component in the overall plan for improving science and mathematics education in the United States. The very nature of the contents of the report suggest that the real interest of the Japanese centers more on understanding the nature of US education, particularly the secondary-higher education link, rather than what lessons might be learned from the US to improve education in Japan. The Japanese appear to have little interest in the science and mathematics programs offered in US schools. In 1985 South Bend, Indiana, Mayor Roger Parent, who was part of a delegation of mayors trying to lure Japanese investment to their cities remarked: "The Japanese told us right off the bat that in science and math, if their kids stayed in American high schools and returned to Japan for college, they'd be two or three years behind ("The Total System", 1985, p. 20). In response to the education problem, Japanese schools have been established worldwide (one each in Chicago and New York) to deal with the academic and social problems experienced by students who return to Japan from abroad. Knowledgeable observers have commented that the Japanese report, Educational Reform in the United States, "...exaggerates appreciation for American schooling out of politeness" (Gordon, 1987, p. 4).

The US report describes the context of education in Japan and presents an overview of all levels of Japanese education, the teaching profession, and the role of the family in education. The US report, however, goes a step beyond that of the Japanese. It identifies the features of schooling that seem to be responsible for the phenomenal success of the Japanese educational system.

Japan is a country with approximately half the population of the United States crowded onto an island about the size of the State of California. With one of the highest population densities of any country in the world, few natural resources, and four-fifths of its land mountainous, unarable, and uninhabitable, human resources are Japan's greatest and perhaps only asset (Ranbom, 1985). Learning is seen to be the keystone for the success of a complex, knowledge intensive, highly literate society. Education has been woven into the cultural, religious, political, and moral fabric of Japanese beliefs and customs. Although considerable learning takes place outside the home, and businesses and government contribute greatly to the success of education, Japanese teachers, nevertheless, play a major role in the success story.

At every level of education teachers have broad responsibilities for transmitting cultural values and instilling a love of learning. Early in preschool licensed professional teachers work with children between the ages of three and five for five hours per day, training them in proper social behavior, habits, and attitudes and providing them with instruction in health, social life, nature, language, music, and crafts as prescribed by the Ministry of Education and the Ministry of Health. Formal entry into elementary schools, grades 1-6, is a ceremonious occasion and is seen to be critical in establishing proper attitude and learning habits. Talented and experienced teachers are therefore more frequently assigned to the first grade. Teachers teach a different grade level each year to gain a broad experience with all six grade levels. The curriculum for the elementary school is prescribed by the Ministry of Education and consists of instruction in Japanese, social studies, arithmetic, science, music, art and handicraft, homemaking (in grades 5 and 6), physical education, and moral education. In science lessons teachers stress that students develop process skills, learn to conduct simple experiments, and gain an appreciation for the biological and physical sciences. The curriculum in all subject areas is demanding and highly structured. In the lower secondary school, grades 7-9, the school climate is more serious and disciplined with teachers placing greater emphasis on the transmission and acquisition of factual knowledge and on further development of the basic skills in preparation for the high school entrance examination. Lower secondary school teachers emphasize mastery of factual material, through the use of drill and memorization, rather than critical thinking. Compulsory education ends with completion of grade 9. Vocational and academic tracks are offered in the upper secondary school, grades 10-12, but approximately 70 percent of all Japanese students enroll in the academic track in preparation for college. Education is rigorous and demanding, with all students, regardless of track, completing the same academic program in grade 10. Grades 11 and 12 are highly structured. Academic students pursue either the literature or science track. Literature majors study biology and chemistry, and science majors study chemistry and physics. Teachers expect much from their students. "Good teachers are considered to be those who carefully and conscientiously cover the material outlined in the course of study" (Leestma, August, George, & Leek, 1987, p. 43). Lessons are intensive and fast paced with little time for enriched presentations or student questions.

It would be unwise to conclude that the success of Japanese students in science and mathematics is merely the product of social, moral, and cultural forces. According to the US report Japanese Education Today, "Japanese teachers are an essential element in the success story. Japanese society entrusts major responsibilities to teachers and expects much from them. It confers high social status and economic rewards but also subjects teachers to constant public scrutiny." (Leestma, August, George, & Leek, 1987, p. 15). Two classes of teaching certificates are available, with different qualifications for each depending upon grade level (preschool, elementary, lower secondary, or upper secondary) and subject to be taught [More credits are required to teach social studies, science, homemaking, industrial arts, and vocational education than Japanese, mathematics, music, art, physical education, health, English, and religion]. A first class teaching certificate at the preschool level requires a bachelor's degree, 28 credits in professional education subjects (including 4 credits, i.e., 4 weeks, for student teaching), and 16 credits in a teaching subject (e.g., science). For a first class certificate to teach in elementary schools a candidate must complete, in addition to receiving a bachelor's degree, 32 credits in professional education subjects (including 4 credits in student teaching) and 16 credits in a teaching subject. Considerably more training in science is required for secondary school teaching certificates. For the lower secondary level a first class certificate requires completion of a bachelor's degree, 14 credits in professional education subjects (including 2 credits in student teaching), and 40 credits in science. For a first class, upper secondary certificate in science a person must hold a master's degree, have completed 14 credits in professional education subjects (including 2 credits in student teaching), and have earned 62 credits in science (Troost, 1985 and Leestma, August, George, & Leek, 1987).

Once formal academic requirements have been completed, a prospective science teacher must receive a license to teach from a prefectural board of education. A prefectural board may require additional academic courses of all applicants. A two part examination is also administered by a prefectural board. First, a science teacher candidate must pass a written examination covering general education and science. Next, the applicant must complete an interview. When a candidate has been successfully examined a teaching license is granted, which is good for life in any of the 47 prefectures and 10 municipalities. The economic and social status of teachers in Japan is high, and competition for teaching positions in Japan is intense, with approximately five applicants for each vacancy.

The strength of the continuing education opportunities available to teachers underscores the Japanese commitment to education and self-improvement. First year teachers receive a minimum of 20 days of inservice training during the year, with much of the training taking place in the beginning teacher's school under the guidance and supervision of an expert experienced teacher. Interestingly, most teachers and boards of education perceive the preservice teacher preparation programs to be weak. Teachers are also active in citywide or districtwide study groups, formed to discuss a variety of instructional concerns. Prefectures and municipalities also have teacher centers, which offer inservice education, counseling, and guidance and conduct research within the district. Programs last from one to five days and offer teachers subject matter, teaching, technology, and classroom management training. Teacher centers have a full-time staff, consisting of experienced teachers on leave to conduct inservice programs, university professors, and community resource persons. Sixth-year teachers are required to spend three days at the center for refresher training. Opportunities are also available for teachers to undertake special projects of their own design at the teacher center for three or six months periods. Teachers find the inservice training they receive at teacher centers and in their schools to be successful (Leestma, August, George, & Leek, 1987, p. 18).

Japanese teachers are active members in professional organizations, which exist for science teachers at all educational levels. By one estimate there are at least twelve national organizations or societies interested in the promotion of science education in Japan and there are numerous regional and prefectural associations. Each society publishes one or more journals, and in 1972, 74 percent of Japanese science teachers were members of a subject-specific science teachers association (Troost, 1985, p. 48).

In the concluding section of the report, Japanese Education Today, Secretary of Education William Bennett summarized what he saw to be twelve major implications for American education. The implications attest to the importance of parental involvement in education, clarity of purpose, motivation, expectations and standards, comprehensive basic education, cultural literacy, character education, school and classroom environment, maximizing learning time, investing in teaching, developing and rewarding outstanding teachers, and teaching students to be responsible and holding them accountable for learning (Leestma, August, George, & Leek, 1987, p. 69-71).

The Problem

The declining quality of science education may be far easier to document than to overcome. Data confirm the achievement test score decline, the change in demographics of the school age population, reduced numbers of students studying science, and a decline in the quality of science teaching and in the attractiveness of the science teaching profession.

Examination of Scholastic Aptitude Test scores (verbal and mathematics) for the last 20 years indicates a decline in average achievement, although more recent data suggest that the decline may be abating (Department of Education, 1985). An examination of SAT scores by ethnicity reveals major gaps in achievement between white, Asian-American, Mexican-American, and black. The SAT-Verbal scores differ among ethnic groups by about 120 points, with black students scoring lowest followed by Mexican-American, Asian-American, then white students. Differences of approximately 160 points are observed on SAT-Math scores, with black students scoring lowest followed by Mexican-American, white, then Asian-American students (Mirga, 1986).

Performance by 9-, 13-, and 17-year-olds on the National Assessment of Educational Progress tests reveals declines in physical science knowledge among all age groups, notably among 17-year-olds, across four administrations - 1969, 1972, 1976, and 1981 (Raizen & Jones, 1985). Sharp regional differences were found in science knowledge on the 1981 NAEP results; southeastern students scored significantly below the national average on items measuring science knowledge; understanding and use of inquiry skills; and understanding of the interactions among science, technology, and society (Hueftle, Rakow, & Welch, 1983).

Declining achievement in science among students in the United States has been well documented, but now there is disturbing evidence that US students lag far behind their counterparts in other countries (Rothman, 1987). Results of the Second International Science Study indicate that American students' performance was at or below the level attained in 1970, when the first international study was conducted. The study examined achievement among students in grades 5, 9, and 12 in two dozen countries.

Moreover, results revealed that students in England and Japan (and six other unnamed countries) outperformed the top American students, who were taking advanced courses in physics, chemistry, and biology. American students taking their second year in a high school science course performed only slightly better than American students in their first year of study and substantially below students from Japan and England. Similar outcomes were noted among non-science students; British and Japanese non-science students outperformed US non-science students.

Most disturbing among all the studies documenting the decline in achievement are results relating achievement to socio-economic factors (Feistritzer, 1985a). Students who potentially stand to profit the most from schooling appear to be the ones least likely to succeed. Results from the High School and Beyond tabulations compiled by the National Center for Education Statistics reveal that:

> Students who live with both parents, come from high-income families, the top socio-economic status quartile, have relatively highly educated parents, with both parents in the home -- these students score highest on achievement test scores,...(Feistritzer, 1985a, p. 1). Students who are poor, in the bottom SES quartile, live with one parent or have some other arrangement, and whose parents have little education -- these score lowest on achievement test scores (Feistritzer, 1985a, p. 1-2).

The rise in numbers of educationally "at risk" children is representative of the major demographic changes that have taken place in the US population over the last decade. All available evidence indicates that the number of "at risk" students will continue to increase. During the last decade when the white population increased by only 9.4%, the black population increased by 17.9%, and persons of Spanish origin increased by 61%. Rapid growth in populations has been recorded in the South and West regions of the US and in cities. One in five children now live below the poverty level, and one in five children live with a mother with no father present. Moreover, five times as many children are born out of wedlock today as in 1970 and more than half of all black children born in 1982 were illegitimate, with half of those born of a teenager.

These dramatic changes call for institutions of higher education to redefine the qualities necessary in candidates to become school teachers and to retrain current teachers to prepare them better for coping with today's students (Feistritzer, 1985a). At risk students may have emotional, social, and learning needs that are altogether different from those of traditional students. Providing instruction to meet the special learning needs of "at risk" students may prove to be difficult. In one research study instruction was matched to selected student characteristics - cognitive style, locus of control, and need level - to improve students' attitude and achievement in physical science (Trout & Crawley, 1985).

Results of the study identified 55% of the 301 student participants as having unfulfilled physiological and safety needs and indicated that matching on one, two, or three characteristics did not improve students' attitude or achievement. Researchers were led to conclude that "Students who are hungry or fear for their safety may loom as the greatest challenge facing educators in this decade of educational excellence" (p. 415).

Data indicate that too many students study too little science (Raizen & Jones, 1985). Teachers spend an average of 17 minutes a day teaching science in grades K-3 and an average of 28 minutes in grades 4-6. Far less time may actually be devoted to teaching topics selected from the biological and physical sciences, since many elementary teachers consider art, music, and health to be science (Pyko, 1987). In grades 7-9, 86% of the students are enrolled in science. Among high school students, greater numbers of males tend to study more years of science than do females. Collectively, students average completing three and a half years of science in grades 10 through 12. Asian and Pacific Island students are more attracted to the study of physics (47%) and chemistry (67%) than are white (21% and 40%), black (20% and 31%), and Hispanic (17% and 23%) students. Students pursuing academic programs study science an average of 2.9 years; whereas their counterparts enrolled in general programs average 2.1 years of science study; and students enrolled in vocational programs average 1.7 years (Raizen & Jones, 1985, p. 101).

That achievement in science has undergone a sharp decline in the past 20 years has been well documented at local, state, and national levels, as has been dwindling student interest in studying science. The complexity of the problem is widely acknowledged, but the blame has come to rest all too often on the declining quality of science teachers. Reports document the decline in academic ability of students planning to become teachers, as measured by scores on SAT Tests (Feistritzer, 1985b). Although the scores of students planning to become teachers have traditionally been lower than those of other students, over the past decade the SAT Test score decline has been more dramatic for prospective teachers than for other students. Today's teacher recruits are drawn from the bottom group of SAT scorers (Darling-Hammond, 1984).

Impending teacher shortages pose major problems for improving the quality of science education offered in the nation's schools. In 1981, fewer than half of the newly hired teachers in mathematics and science were certified or eligible for certification in the subjects they were assigned to teach (National Center for Education Statistics, 1983). The National Science Teachers Association noted that among the 200,000 mathematics and science teachers in 1982-83, 9% left teaching, 30% were not fully qualified to teach the subjects they were assigned to teach, and over 40% planned to retire within the next decade (Aldrich, 1983). Teacher supply and demand projections have been developed by numerous agencies, and each agency arrives at different projections based on the data it uses. The problem of determining whether a teacher shortage really exists or will exist in the future has been the subject of considerable debate. Reasons for the differences in conclusions reached center on the question of certification vs. qualification to teach, differences among the states as to the rules for certification, differences in projected numbers of persons available to teach, and the extent to which misassignment of teachers occurs (Olson & Rodman, 1987).

Academically talented persons are seldom attracted to teaching, the reports show, and those who do become teachers are among the first to leave the profession. Studies conducted in North Carolina revealed that academically talented teachers were among the first to leave teaching, lured from the profession by improved working conditions and higher paying jobs, and that teachers who scored lowest on measures of academic ability were most likely to remain in teaching (Schlechty & Vance, 1981). Subsequent analyses using data from a national sample confirmed conclusions reached with the North Carolina sample and further found teaching to be more attractive to persons with low measured academic ability than to those persons with high measured academic ability (Vance & Schlechty, 1982). In a more recent national sample, 27% of all teachers said they are likely to leave teaching in the next five years, reaching a high of 36% among urban school teachers. Among award winning teachers, 39% said they expect to leave teaching soon (Shankar, 1985).

Schools and school districts throughout the nation have been placed in a bind. Increased course and graduation requirements in science necessitate the hiring of more and better qualified science teachers. Unable to find qualified or certified teachers some school districts have resorted to hiring uncertified teachers (Currence, 1985) and "making do in the classroom." In the report titled "Making Do in the Classroom: A Report on the Misassignment of Teachers" (Robinson, 1985), the Council for Basic Education and the American Federation of Teachers provided state by state documentation to show that assigning teachers to teach subjects for which they have little academic preparation is completely legal. Faced with the task of offering more sections of existing science courses, school districts have hired uncertified teachers (Currence, 1985) and exercised their legal authority in assigning teachers to teach courses in "critical shortage" subjects, such as science and mathematics, for which they have limited academic preparation. Unfortunately, only a few states maintain records to document the extent to which teachers are misassigned. State of Utah records document for the 1983-84 school year the percentage of teachers who had major teaching assignments in subjects for which they had neither a college major nor minor - 75.8% in general science, 82.1% in earth/space science, 43.1% in physical science (Robinson, 1985, p. 23). Records for the state of Virginia indicate that 33.59% of the teachers assigned to teach earth science or general science did not hold endorsements in these fields (Robinson, 1985, p. 24). In Texas, a state in which records on out-of-field teaching are not kept, a school district need only issue to any certified teacher an Emergency Permit (less than 12 semester hours preparation) or a Temporary Classroom Assignment Permit (12 or more semester hours preparation). No records are maintained by the Texas Education Agency as to the extent to which school districts issue either Emergency or Temporary classroom Assignment Permits. The misassignment of teachers is both legal and a common practice.

Teaching appears to have lost its appeal (Darling-Hammond, 1984). Beginning salaries are lower than those in virtually all other fields requiring a bachelor's degree and they have continued to lose ground over the past years, even when adjustments are made to reflect a 12 month salary equivalent. Moreover, teachers' salaries reach a ceiling much sooner and at a much lower level than do the salaries of other college-educated workers. Asked if they would still become a teacher if they could start over again, nearly 40% of the teachers surveyed in 1980-81 said "no" (Darling-Hammond, 1984, p. 11). The best qualified teachers are the most dissatisfied, citing salary and working conditions, bureaucratic interference, lack of administrative support, and too little autonomy as reasons for their dissatisfaction.

The decline in science achievement combined with dramatic changes taking place in the profile of the school population will present formidable challenges to science teachers in the coming decade. Talented, highly skilled science teachers will be needed. Unfortunately, the reforms that have been proposed (and enacted in many states) may further exacerbate the disparities between the educational needs of tomorrow's students and the abilities and capabilities of persons who want to become teachers.

Reform

The year 1983 has been called the Year of the Report on Education (Education Commission of the States, 1983). During the short timespan of a year, nine major reports had been released advocating major changes be made in precollege education. The changes called for in the reports, if enacted, would place enormous strains on the Nation's teaching force, particularly persons teaching science and mathematics. *The Paideia Proposal* (1982) presented a philosophy of how all students should learn and teachers should teach. Governors and business leaders joined forces to emphasize the connection between education and international competitiveness in the report *Action for Excellence* (1983). That same year the National Science Board's Commission on Precollege Education in Mathematics, Science and Technology issued the report *Educating Americans for the 21st Century* (1983) in which the importance of mathematics, science, and technology were stressed (along with the humanities) for all students regardless of ability or interest. *Academic Preparation for College*, published by the Education Equality Project of the College Board (1983) spelled out what students should know and be able to do after twelve years of schooling. The federal role in education was the topic of the report *Making the Grade* issued by the Task Force on Federal Elementary and Secondary Education Policy of the Twentieth Century Fund (1983). The National Commission on Excellence in Education (1983) in its report *A Nation at Risk* also focused on elementary and secondary education, emphasizing the shortcomings of the present educational system and calling upon its readers to demand more from schooling. A summary of the actions and policy changes underway in education was presented in the Southern Regional Education Board's (1983) report *Meeting the Need for Quality: Action in the South*. It is important to note that only two of the major reform reports issued in 1983 are based upon research studies and field work, *A Place Called School* (Goodlad, 1983) and *High School: A Report on Secondary Education in America* (Boyer, 1983). The lack of a research base for most of the reform reports has not gone unnoticed.

> A strong plebian [sic] caste is evident as the reform movements are reported as modern expressions of populism. Chester Finn writes that the 'reforms are more concerned with results than pedagogy, and the major movements have been composed by laymen. Because of this they have never had the support of the academic research community.' In the words of people from each coast, 'The [movement] is the opposite of rational; the reports are not research reports, and the political leaders' responses are rarely based on careful research.' 'People would be horrified to discover how superficial the bases for many of these changes are.' (Chance, 1986, p. 2).

The Nation at Risk report (National Commission on Excellence in Education, 1983) had significant shock effect and was intended to present a compelling argument that public attention was needed to improve the quality of precollege teaching and learning. It stated the problems of education in a particularly poignant and effective language. Its authors alerted the public to the impending doom facing the Nation - "...the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people;" "if an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war;" and "the average graduate of our school and colleges today is not as well-educated as the average graduate of 25 or 35 years ago...." The report also identified five new basics and their requirements - four years of English, three years of mathematics, three years of science, three years of social studies, and one-half year of computer science, with two years of a foreign language for the college bound.

The National Science Board's Commission on Precollege Education in Mathematics, Science, and Technology (1983), rather than recount the many studies documenting the decline in the quality of education, issued a set of recommendations for improving the quality of mathematics and science education, defining these subjects as part of the "new basic" needed for all children. The NSB Commission's report Educating Americans for the 21st Century (1983) called for prompt action at the federal level: "By 1995, the Nation must provide, for all its youth, a level of mathematics, science and technology education that is the finest in the world, without sacrificing the American birthright of personal choice, equity and opportunity" (p. v).

The NSB Commission called for dramatic changes in precollege science and mathematics education in an effort to improve student achievement. The Commission's report urged strong leadership at all levels - appoint a National Education Council to oversee implementation of Commission's recommendations, establish a Governors Council in the states to develop and monitor change programs, foster partnerships with business, government and academia to address problems at the local level, and monitor student achievement and participation in science in such a manner that enables local, state, and national evaluation and comparison of progress. "Excellence and elitism are not synonymous" (NSB, 1983, p. vii), in the language of the Commission's report, and all students are to be expected to gain an understanding of mathematics, science, and technology. National,

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state, and local governments are to be called on to establish landmarks of excellence - exemplary or model programs, in which students of diverse backgrounds exhibit high achievement and schools have strong ties to local resources. The Commission also called for more science to be taught in elementary schools and for secondary school students to be required to take more science and mathematics for graduation. Curriculum development and evaluation, research into the processes of teaching and learning, evaluation of the new technologies available for learning, and integration of informal learning experiences into the lives of students received strong endorsements in the Commission's report.

The NSB Commission's report also called for sweeping changes in the professional education of science and mathematics teachers. Teachers were identified as the key ingredient in motivating and maintaining student interest in mathematics, science, and technology. Initiatives were urged on three fronts: retraining current teachers, improving the training of incoming teachers, and locating qualified teachers from non-traditional sources. Federal funding was urged for retraining programs in science for all elementary and secondary school teachers to be offered in each state over a five year period and for seed money to develop and establish statewide or regional on-site teacher training programs using the new information technologies. Higher admissions, curriculum, and graduation standards were advocated for mathematics and science teachers, including a strong background in mathematics and science for prospective elementary school teachers and an academic major in college mathematics or science for prospective secondary teachers. Industry, universities, and the military were cited as likely sources of retired scientists, engineers, and teachers to fill the gaps existing in the science and mathematics teaching force. To meet the continuing education needs of science and mathematics teachers, the NSB Commission advocated that "Every state develop at least one regional training and resource center to provide a variety of supporting services for mathematics and science teachers (including computer instruction and software evaluation). These centers could also serve as a local focus for the participation of business, educators and government, and would include equipment for assistance in technology instruction" (NSB Commission, 1983, p. 35).

The professional education of teachers has been the subject of reforms proposed by the Holmes Group and the Carnegie Forum on Education and the Economy. Formed by Deans of Colleges of Education at major research institutions in the nation to explore ways to improve teacher education programs and the teaching profession, the Holmes Group's efforts resulted in the publication of Tomorrow's Teachers (Holmes Group, 1986), in which a program of reform is proposed, obstacles to change are described, and a commitment to action is affirmed. The task of improving teacher education programs and the teaching profession rests upon two assumptions: "the best educator is the one who is best educated and the real professional is one who is permitted and encouraged to use expert knowledge and skill autonomously in the intelligent and responsible delivery of high-level services" (Soltis, J.F., 1987, p. 311).

The Holmes Group proposes major changes in the licensing of teachers, establishing a three-tier system. The beginning teacher is issued a nonrenewable, temporary license, which is good for five years. The first professional certificate, the Professional Teacher Certificate, would be granted only to teachers who had completed a master's degree in teaching. The highest level certificate, the Career Professional Certificate, would carry the additional requirements of outstanding performance in the classroom and advanced academic training.

The differentiated staffing proposed by the Holmes Group may be counterproductive. Many schools and school districts strapped with financial pressures to reduce school budgets and the cost of education will be forced to hire large numbers of instructors at lower costs (Apple, M. W., 1987). The most highly trained teachers will most likely be found in schools that offer attractive working conditions and salaries. Newly licensed teachers will be hired to teach in lower paying school districts and placed in schools in which the working conditions are less attractive. These schools tend to serve less-advantaged students, who pose greater challenges to school staff, resulting in fewest resources being allocated for supervision and school improvement in those schools that need them the most (Darling-Hammond, 1987, p. 357).

The Holmes Group also proposes changes for universities and schools. Among the changes for universities are the elimination of the undergraduate education major, strengthening education in the academic subjects, developing coherent programs of advanced study in teaching emphasizing research on human cognition and subject specific teaching and learning. Schools and universities are urged to form stronger links with one another by establishing professional development schools, bringing teachers, administrators, and university faculty together to improve teaching and learning, sending expert teachers into the universities and more university faculty into the schools. The partnership between universities and schools would ultimately improve the quality of teaching and learning for all students and at the same time provide coordinated training programs for prospective teachers. Creating professional development schools in places where large numbers of new teachers are employed would also help to improve the quality of education in schools unable to attract highly experienced, competent teachers (Darling-Hammond, 1987, p. 357).

The report of the Carnegie Forum on Education and the Economy (1986), A Nation Prepared: Teachers for the 21st Century, calls not for repairing the nation's educational system but rebuilding it "...to match the drastic change need in our economy if we are to prepare our children for productive lives in the 21st century" (p. 14). What is called for in the Carnegie report is improved education to strengthen the nation's economy, although it has been noted that there are no data to suggest that science education actually increases economic productivity (Champagne & Hornig, 1987, p. 11). To improve teaching, the Carnegie report advocates a national board for certification, restructuring schools to provide a professional environment for teaching, restructuring the teaching force, bringing more minorities in the teaching ranks, relating incentives for teachers to students' performance, requiring a bachelor's degree to begin professional study, and developing the master of teaching degree. Most dramatic among the many reforms proposed in the Carnegie report is the call for a four-tier teacher salary scale ranging from $18,000 to $25,000 per year for licensed, non-certified teachers to $52,000 to $72,000 per year for lead teachers employed in wealthy school districts.

Major changes have been proposed in high school graduation requirements and curriculum standards since the flurry of education reform reports released in 1983. By 1985 forty-three states had raised high school graduation requirements, with some states establishing special diplomas for college bound students (Staff, 1985). Virtually all reform reports condemned the practice of assigning students to separate tracks, citing many self-image and motivation problems students experienced who are assigned to the low, non-college bound, or vocational track (Felt, 1985). In most states graduation requirements in science, which had remained unchanged for 25 years (Department of Education, 1985), were raised from one to two years, with some states still requiring only one year but others requiring 3 years. A few states included the additional stipulation that one or both of the two years required in science be met with a laboratory science course (e.g., Rhode Island, South Dakota, Washington). The NSB Commission recommended three years be required in science and technology education (including one semester of computer science) for high school graduation. In the Source Materials (NSB Commission, 1983) reports from working groups in biology, chemistry, and physics unanimously recommended a reduction in the number of topics covered in a typical course in favor of an indepth coverage of basic principles and integration of the sciences. Biology, chemistry, and physics courses should stress the acquisition of subject-specific knowledge and utilization of the knowledge in personal and social contexts.

From government commissioned reports to local task force studies, almost everyone agrees - more science needs to be taught in the schools but a different kind of science is needed (Jackson, 1983). The kind of science needed has been the subject of considerable debate in the community of science educators. What should be the goals of science education - knowledge acquisition (pure science) or knowledge utilization (science/society)? Advocates of the science/society emphasis stress the interrelationships between science and society and recommend this emphasis comprise the domain of science education. A "new vision" of science education is needed because in most courses science is taught more as a vocabulary than at a cognitive level that has a potential for critical thinking and application, which fails to meet the intellectual and knowledge demands of a science and technology oriented society (Hurd, 1984). What is called for is a redefinition of science education to be the study of the science-society interface. Emphasizing the mutual interaction between science and society offers better justification for the study of science in grades K-12 and provides greater opportunity for research in science education to affect practice (Yager, 1984). The new approach would better serve the needs of all students, not just future scientists, and would remove the elitist view of science education (Yager, 1985). Critics argue that a study of the science/society interface overemphasizes the sociological and political aspects of science education and assert that science education is the "...discipline that bears the responsibility of leading students to learn how to search for knowledge in the biological and physical worlds." (Good, Herron, Lawson, & Renner, 1985, p. 140). The debate centers on the distinction between education in science and education about science, and each view addresses different populations of students (Barrentine, 1986). Both camps have been criticized for failure to recognize education as a social institution which must provide for the needs and continued development of individuals and at the same time fulfill the requirements and aspiration of a democratic society (Bybee, 1987).

There appears to be more to the pure science vs. science/society debate than meets the eye. The confusion about purposes reflects the general American debate about excellence and opportunity, whether the requirement is for more excellent scientists identifying and drawing on all the available student talent, or an entire work force which has well-developed skills and knowledge in mathematics, science, and technology. "Either way leads to reforms in the formulation of science education but the task facing the teacher is quite different in each case." (Harvey & Marsden, 1986, p. 138). To improve the nation's economic competitiveness in the international marketplace requires workers with a high degree of scientific and technologic literacy. The ways of pure science, stressing an analytic conceptual style and high levels of analytic abstraction, are not central to most contemporary occupations, resulting in a mismatch between the objectives of science education and both the conceptual styles schools seek to develop and the market for these skills (Cohen, 1987).

Teacher preparation and advanced academic training will be in great demand as local school districts struggle to meet the challenge of expanded graduation requirements, to develop and make available to students science programs responsive to the needs of society in the 21st century, and to improve the quality of teaching and learning for an ever-increasing heterogeneous group of students. Continuing education will play a central role in meeting the needs of teachers seeking the advanced training or, for example, an Advanced Certificate, as is required of teachers seeking to reach level three on the proposed Carnegie salary scale. According to the Carnegie report, "These candidates must be acquainted with work at the frontiers of the subjects they teach....familiar with a wide range of sophisticated materials, emerging uses of technology, and approaches available to help students with especially difficult problems." (Carnegie Forum, p. 78).

Continuing Education

Institutions of higher education have historically played a key role in reforming and improving precollege science education. Their contributions to current reform efforts have the potential to be no less significant than they were just three decades ago when the NSF relied heavily on the talent of scientists and science educators to chart and direct its extraordinary experiment in curriculum development. Today a different type of involvement is needed. Reform reports of the 1980's call for development of "science for all," a true K-12 program in science education, not another overhaul of precollege science education programs to better prepare people for university study in the sciences.

Higher education must commit its resources to charting and directing an improved program of K-12 science education through the work of its centers of science (and mathematics) education. Traditionally, however, there has been little reward in research universities for faculty who spend their time working with schools and school systems. Many questions remained unresolved regarding the role of the research university with the newly proposed programs of professional education (Lieberman, 1987). In accordance with new needs, centers are best positioned within the university and school communities to bring together scholars in science, science education, education, and persons in the business community to collaboratively work for the improvement of K-12 science education programs through research and development - in preservice science teacher preparation programs, in graduate programs in science education, and particularly in continuing education. Preservice science teacher preparation programs have been the subject of study by various prestigious commissions, and their recommendations have been discussed in this chapter. Moreover, graduate programs in science education are frequently reviewed and evaluated in an effort to make the courses and experiences offered to graduate students more responsive to the needs of scholars and practitioners (e.g., Barufaldi, Crawley, Holliday, & Yeany, 1987).

Continuing education programs have a history of neglect by higher education. They have represented little more than special training sessions hastily conceived and poorly organized by school district officials, usually led by a paid consultant, to meet local and state requirements for inservice training with very little research utilized to guide practice. To add to the problem, scant mention has been made in recent reform reports of the need for and role of continuing education as an essential support system to sustain any gains that may be realized as a result of recent educational changes enacted at the local, state, and national levels. Continuing education programs in science education offer a means for higher education institutions, through their centers of science education, to make a long term commitment to improve K-12 programs in science education at the local level. Centers are best suited to establish, maintain, and sustain K-12 science education programs that develop a high degree of science and technology literacy among all students, rivaling the level attained by the Japanese.

Continuing education programs are envisioned to include the following components: research, inservice, summer institutes, local consortia, and clearinghouses. Though identified as one of five components, research is both unique and common to all aspects of continuing education programs for science teachers. Research alone is insufficient when isolated from professional practice. Conversely, professional practice isolated from research contributes little to the overall improvement of the knowledge base in science education and the improvement of the science education profession.

Research is an essential ingredient in the continuing education of science teachers. Although there are many local and regional problems related to science curriculum, students, teachers, and instruction, there are basic questions common to all teaching and learning in science education that demand immediate attention from researchers in centers of science education. These basic questions were the subject of a conference sponsored by the Lawrence Hall of Science, the Graduate School of Education at the University of California, Berkeley, and the National Science Foundation (Linn, 1986). Recommendations were made for researchers to build a strong foundation for needed innovation in science education by understanding the nature of science learning, "...to explore in greater detail such questions as how students develop a world view, reason about new information, and solve problems in science." (Linn, 1986, p. 23). Easy answers to the questions are not likely to be found, given the declining quality of science teaching and learning, the dwindling supply of qualified science teachers, the fast increasing numbers of "at risk" students, and the diversity of conceptual styles students bring with them to the classroom. Once a better understanding of science teaching and learning is developed, strategies must be explored to insure more effective and timely use of research findings. Centers of science education are envisioned to play a key role in both the development and implementation of the research findings.

Centers of science education are ideally positioned within the university and school communities to develop and conduct inservice education programs designed to bring about needed changes in science teaching. First, inservice education programs must provide opportunities for underqualified science teachers to improve their knowledge of fundamental concepts in the science course(s) they are assigned to teach. Even among qualified, experienced teachers knowledge is likely to be outdated and in need of updating. Second, inservice education programs offer an excellent opportunity to disseminate research findings to teachers to improve the quality of science teaching and learning of all science students. The traditional approach to science teaching is to offer one mode of instruction to all students. Aiming towards the middle may serve the learning needs of only one third of the students. Mastery learning and teams games tournaments are two instructional innovations few teachers make use of that have been shown to be effective with diverse as well as more uniform groups of students (Walberg, 1983). Third, inservice education offers an effective means for providing teachers with the training needed to get them involved in conducting research in their science classrooms. For example, the "Every Teacher a Researcher" project sponsored by the National Science Teachers Association's Research Committee has shown teachers to be eager to become involved in research that they perceive to directly impact instruction (Gabel, 1986). Research on the misconceptions students bring to physical science instruction, for example, offers teachers an opportunity to explore an area of science teaching and learning with profound implications for the nature and kind of instruction offered to students (Minstrell, 1982). Regardless of the type of training offered, inservice education must be viewed as a problem of instructional change in schools in addition to program and faculty development, and numerous organizational constraints must be considered if the program is to become part of a continuing educational effort (Carey & Marsh, 1980).

Summer institutes have long been attractive options for teachers to upgrade their content knowledge and teaching skills. When planned in cooperation with science faculty, science teachers, and business representatives, summer institutes have the potential for bringing about major changes in teachers' understanding of science/technology and effective science teaching practices and subsequently improving the level of understanding of science and technology acquired by science students. One of the most memorable and professionally rewarding aspects of the NSF curriculum project era for science teachers in the 1960's were the institutes. Prior to this time most science teachers were isolated from teachers within their school district and seldom met with other teachers within their state and region. With the advent of the NSF's summer institutes, teachers were brought together to learn more about the subject they taught, exchange ideas, share problems, and become affiliated with a core of university and school persons who shared a mutual interest in instructional improvement.

The dissemination type of institute of the NSF curriculum project era is not what is needed today. The demands of a new information society are to improve the science education of all children, not just the few who may be interested in pursuing careers in science or engineering. Summer institutes must be responsive to the science education needs of the local community - for improved curriculum, for improved teaching methods, for improved means to relate science with the community and other subject areas, and for renewal of teachers' skills and interest in science education. Needs of such proportion require careful, systematic planning, recruitment and selection, program development and operation, participant support, evaluation and follow-up (Council for Basic Education, 1985). Teachers who excel in summer institutes might join a cadre of local resource staff and be enlisted to work with science teachers throughout the district, state, or region conducting inservice education programs and serving as assistant instructors in subsequent summer institutes.

Local consortia provide an opportunity to bring together a cadre of persons to form a community of professionals who are interested in developing and sustaining science education programs that address local needs. Modelled after academic alliances (see for example Livermore, Roth, & Stamm, 1986 and Gaudiani & Burnett, 1985), local consortia offer the possibility of developing and sustaining a renewed excitement among science teachers for teaching science. Centers of science education are in the unique position to foster collaborative arrangements among science teachers, parents, local business representatives, professional associations, and university science faculty. The purpose of the local consortium is to provide science teachers with an opportunity to meet regularly to: (1) discuss instructional problems and concerns, (2) describe "model programs" in operation in their schools, (3) acquire information about projects on the frontiers of science and technology within the local community, and (4) learn about recent research results of importance to science teaching practice. Consortia could serve as a vehicle to keep teachers informed about national and international research projects in science education, to help teachers obtain outside assistance with local instructional problems, and to initiate research projects. For example, projects might address the problems of teaching "at risk" students, attracting women and minorities into science and science teaching, using investigative approaches to teach science, using informal science learning opportunities to enhance formal instruction, and enlisting parental support for science teaching and learning. Consortia offer an excellent forum to inform teachers of cross-cultural comparisons of science achievement and learning, especially when the results offer helpful insights for improving local programs. For example, science teachers need to be informed of the differences in parental beliefs and attitudes regarding children's academic performance in Japan and the United States (Stevenson, Lee, & Stigler, 1986).

Centers of science education can serve as clearinghouses and resource repositories for locally developed curriculum materials that have been shown to be effective and for old and new science curriculum materials. Few of today's practicing science teachers had the opportunity to participate in a summer institute during the 1960's or make use of any of the many curriculum materials developed with funding from the NSF. Unknown to most teachers, projects developed during this era contain many novel, inquiry-based, process-oriented activities and investigations designed to teach one or more basic concepts in a specific subject field and can be used successfully with students of above average abilities and interest in science. Copies of textbooks, teacher's guides, laboratory manuals, and other supplementary material developed with NSF funds, though not commercially available today, can be located and purchased from companies who specialize in the sale of out-of-print books, and made available to science teachers. Professional science and science teachers' associations have sponsored curriculum development projects targeting specific groups of students and specific curriculum objectives; the American Association for the Advancement of Science is but one example of a professional association that has developed curriculum materials and assistance programs for teachers in response to the current crisis in science education (Staff, 1986).

Continuing education programs for science teachers offer an exciting opportunity for institutions of higher education to become active partners in improving the quality of science teaching and learning, grades K-12. Furthermore, the special knowledge and skill of faculty in centers of science education offer the nation's schools an invaluable resource for the improvement of science education for all students, regardless of their career or educational goals. Through a carefully planned and organized program of continuing education university science educators have a rare opportunity to become involved in active research programs that can have a lasting impact on the practice of science teaching.

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CHAPTER 7

Defective, Effective, Reflective: Can we Improve Science Teacher Education Programs by Attending to Our Images of Teachers at Work?

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Our standard assumption is that research can improve teaching and teacher education, and that the process is rather direct and straightforward. Even though curriculum innovation and implementation are now research areas in their own right, taking on increasing complexity as research proceeds, we seem not to have reexamined our assumption. It is easier to do more research than to ask how research improves teaching. The education of teachers of science is as problematic as any curriculum area, because our assumptions of the relationship between research and practice are based on those that apply in the natural sciences.

This brief chapter is constructed on the contrasts among three images of teachers. Many images are possible, but I was intrigued when I noticed the phonetic similarities among three very different images: Are teachers best thought of as defective? Our traditions of supervision in both preservice and inservice context seem to rely heavily on this image, as "experts" observe and then suggest changes to improve one's teaching. Or are teachers better thought of as effective, as recent research on teacher effectiveness would suggest? If we can show all teachers how their most successful colleagues teach, the evidence that those practices are effective may encourage their use by most or all teachers. Or, as Schon (1983) suggests, should we think of teachers as reflective, developing their professional knowledge-in-action by uniting research and practice, continually reframing their world of work in response to puzzling or surprising events of practice?

The term "image" is used in its very broadest sense, with special interest in how we see the science teacher's practical knowledge in relation to research and to experience. As I explore the consequences of Schon's perspective for activities in science teacher education, I am impressed by the suggestive power of the reflective image. My task in this chapter is to develop comparisons among the three images -- defective, effective, and reflective -- to illustrate why I believe that we will see the greatest improvements in science teacher education when we shift our premises from images of teachers as defective or effective to an image of teachers as reflective about their work. I make no assumption that the shift will be quick or easy. It will require a reflective stance among science teacher educators as well.

HOW DOES RESEARCH RELATE TO PRACTICE?

In the analysis that follows, I draw on the contrasting perspectives presented by Schon (1983) in The Reflective Practitioner. Schon argues that our culture in general and our universities in particular assume a model of "technical rationality," with problems of professional practice indicating what research is required to inform further practice. Those who do the research are not those who experience the problems of practice. Those who practice their profession with clients are not those who do the research, yet they are expected to improve their practice by applying the results of research. If the relation of theory to practice is a direct one, as suggested by our everyday language ("putting theory into practice") and by our school-university relationships (researchers based in universities are the ones who study what happens in schools), then the images of "defective" and "effective" teachers serve us rather well. Teachers are judged on their teaching behavior; researchers are judged on their ability to think about how teachers teach.

The "Defective" Image

Those who know "theory" can use theory to recognize "defects" in teaching behavior. Supervision can then be seen as a process of telling teachers what their defects are, so that the defects may be corrected. The tradition goes back to the early decades of the century (Callahan, 1962). Somehow, clinical supervision (Goldhammer, 1969; Cogan, 1973) persists as a poorly understood and time-intensive variation that resists the "defective" image, by including procedures that involve the teacher as well as the supervisor in the analysis of observed teaching. Those who study curriculum innovation and implementation understand very well that the major science curriculum development projects of the 1960s (PSSC, BSCS, Chem Study, Project Physics, and so on) made similar assumptions about theory being put into practice directly and easily. The implicit image was that of the "defective" teacher, presenting out-dated content with teaching strategies that failed to develop valid views of the nature of scientific inquiry.

Replacing old content with new proved easier than replacing old teaching strategies with new. Summer institutes for science teachers focused on correcting ("defective") teachers' knowledge deficits, and did so with teaching strategies that fell far short of the new ones that teachers were expected to use. McKinney and Westbury (1975) paint a detailed picture of how one group of science teachers reverted to the "traditional" science curricula, after the federal funds accompanying the new materials had been used to renovate old laboratory facilities and purchase new equipment. The teachers could and did think about what they were doing, and the "defective" image did not succeed. The report by Welch et al. (1981) updates the 20-year experience of seeking more "inquiry" in the teaching and learning of science.

The "Effective" Image

Perhaps encouraged by concern about declining achievement scores in some jurisdictions, several types of research in the 1970s focused on the "effective" teacher. The names of Good and Brophy are closely associated with efforts to identify relationships between clusters of teaching behaviors and test scores of student achievement. Good, Grouws, and Ebmeier (1983) show the results of this approach in the study of elementary mathematics teaching. The work by Fisher et al. (1980) produced the concept of "academic learning time," and materials now available from organizations such as the Association for Supervision and Curriculum Development show how strong is the pressure for teachers to become more "effective" by increasing the proportion of time that students are "on task" with medium to high success rates. Researchers' implicit emphasis on teachers being "effective" is also apparent in studies of teacher thinking that focus on decision-making strategies of successful teachers.

The "effective" image seems to be the positive side of the negative perspective in the "defective" image; the direct relationship between theory and practice remains the same. If one knows what research has shown to be "effective practice," then one is in a position to observe teachers and identify ways in which they can become more "effective." This position may be applied individually or in group activities of inservice education or staff development. Again, the basic model for the transmission of research knowledge applies: tell teachers what effective practices are and expect them to adapt their practices accordingly, with little difficulty.

The "Reflective" Image

Schon's (1983) analysis of the relationship between research and practice across many professions helps to explain why the images of "defective" and "effective" practitioners are so widespread, and why alternative images are so difficult to sustain. Schon traces the roots of "technical rationality" to our universities and their decision, late in the nineteenth century, to attach the highest importance not to teaching but to research that would produce new knowledge for the solution of problems of professinal practice. The essential implication is that research is separate from, not an integral part of, the work of the practitioner. For Schon, the most telling consequence is that the practitioner's "knowledge-in-action" goes unrecognized, ignored in our efforts to improve professional practice.

Schon goes on to sketch the outlines of an epistemology of knowledge-in-action, in which the central element is a process termed "reflection-in-action." This is, of course, the source of the image I designate as "reflective," in contrast to the "defective" and "effective" images built on the epistemology that we have all come to take quite for granted. I will not detail here the epistemology of reflective professional practice that Schon sees at the heart of artistic practice that improves by reframing one's work in response to puzzling and surprising events. My specific interest is in the resulting integration of research with practice, practice with research.

CONSEQUENCES OF A RESEARCH-AND-PRACTICE PERSPECTIVE

There are many reasons why it will take us decades to make significant changes in science teacher education, even if the alternate epistemology outlined by Schon is taken up by significant numbers of science teacher educators. Perhaps the greatest challenge to change will be the researcher's need to define an alternative role, based on research purposes other than telling others how to be less "defective" or more "effective." One obvious route is for the science teacher education researcher to become "reflective" about the practices of science teacher education. All that has been taken for granted for so long now has the potential to become problematic. Where is the literature in which we deal, individually and collectively, with the puzzles and surprises of science teacher education?

Learning how to Teach

My own early attempts to relate Schon's argument to my work in a preservice methods course for beginning biology teachers have led me to assert that we do not *understand* the process of learning to teach. We have always known that practice teaching is the most valued aspect of our programs, but we have assumed that our courses make *some* useful contributions to the process of learning to teach. We have assumed that what we can *tell* our students about teaching science and what simulated experiences we can provide in the university setting can be translated by our students into improved *action* as they begin to acquire science teaching experience.

Perhaps we should see it as remarkable, puzzling, even surprising, that so many beginning teachers survive the first year of teaching, that most intensive and exhausting of the years now being designated as a period of "induction" into the teaching profession. Those of us who have learned to teach have survived those early years, but we rarely seem to understand *how* we learned to teach. We tend to remember our first years of teaching with a sense of relief that the work did become easier, less complex, and less time-consuming. *No one asked us* what it was like to learn to teach, and today *few of us ask* our students what it is like for them to learn to teach. Although it seems valuable to recognize that there are stages in a teaching career (see Benner, 1984, for an interesting account of stages in a nursing career), "induction" may be an unfortunate and misleading term. It is not at all obvious that those with experience recognize the importance of helping the novice make sense of experience. Making sense of early teaching experience would seem to be part of a process of becoming "reflective" about one's teaching practices.

The Challenge to Teacher Education Programs

The contrast between an epistemology of technical rationality and one of reflective practice (Schon, 1983) places our present science teacher education programs squarely among those who hold images of science teachers as "defective" or "effective." We see novices as lacking in the many skills of teaching. In fact, they are very familiar with teaching, but they lack experience _of_ teaching. To modify science teacher education by incorporating findings of teacher effectiveness research is _not_ a fundamental shift or improvement in our enterprise. Both "defective" and "effective" images neglect the role of experience in becoming a science teacher and the role of practical knowledge in becoming a better science teacher.

To see science teachers as "reflective," rather than "defective" or "effective," is to adopt a distinctively different view of science teacher education, both preservice and inservice. To "see" the potential of the "reflective" image of the science teacher requires one to begin to be reflective about one's own science teacher education practices. By attending to the role of experience in learning to teach, or to teach better, we move toward a new view of the relationship between research and practice. We have never made much progress in developing the "theory" that, following science, we assumed was the goal of research in science education. We have never had much evidence that the theory we teach can be related to practice directly. Perhaps that will make it slightly easier to develop a new image of research linked to a "reflective" image that credits science teachers and science teacher educators with the ability to be aware of and reflective about the effects of their day-to-day practices as teachers.

The "defective" and "effective" images have long encouraged us to take it for granted that science teacher education programs should be designed as though theory and research can be put into practice directly. With a "reflective" image of teachers at work, our science teacher education programs and our associated research would be very different. I believe that this image has the potential to generate profound improvement in our enterprise. It may also yield the appealing benefit of our coming to understand how one learns to teach. We may even be able to explain to teacher education's many critics why teacher education is so complex, and so easily misunderstood.

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CHAPTER 8

Exposing the Myth of Scientific Thinking in Teacher Education Programs

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INTRODUCTION

The concern of this chapter is for what is known variously as "scientific thinking," "the processes of science," "scientific processes," "inquiry skills," and, sometimes, "scientific method." All these, which here will be termed "scientific thinking," have become significant in science education and in the preparation of science teachers, as I show below. Normally, the popularity of any concept or approach in the literature of science education is no cause for agitation. But the case of "scientific thinking" is rather different, because the concept itself is problematical. And as a consequence, everything that we do with it in the name of teacher preparation becomes problematical. Indeed, there is a very real danger that talk about "scientific thinking" can mislead future teachers of science, thereby limiting their ability to reflect critically upon their own professional practice as well as upon the research literature that seems meant to inform their practice. This is why this chapter addresses improving science teacher education programs by inspecting basic concepts. The concept in question here is the concept of scientific teaching, and the argument is that it must be attended to thoroughly.

Two basic ideas are central to the argument that follows. The first is the notion that "scientific thinking" is a myth that says "Scientific thinking is the most powerful of all types of thinking available in the disciplines of knowledge. It is the way in which scientists do their work, and it is all there is to the intellectual work of science." The second is the view of professionalism that says "There is no professionalism without critical reflection, and critical reflection in science education demands a knowledgeable appraisal of the area's research, texts, and beliefs."

The chapter begins with three separate arguments, each supporting a particular claim:

1. Science does not have exclusive rights to "scientific thinking."

2. "Scientific thinking," as usually portrayed, bears little relationship to how we actually think.

3. "Scientific thinking" is promoted in "methods" texts and in the science education research literature.

The final section of the chapter returns to the opening theme of critical reflection, and makes the case for giving full attention to conceptual analysis in science teacher preparation programs.

ARGUMENT ONE: THE QUESTION OF EXCLUSIVE RIGHTS

The point of Argument One is to show that it is a mistake to think that what commonly passes as "scientific thinking" is the exclusive property of science. To be clear on this, it helps to begin by recording what "scientific thinking" is taken to mean, using pieces from the science education literature. Here, for example, is an item from the Psychological Corporation's Processes of Science Test (Biological Sciences Curriculum Study, 1962):

> Several similar rosebuds were selected for an experiment. Half the buds were placed in a liter of tap water; the other half were placed in a liter of similar tap water in which aspirin had been dissolved. The most general hypothesis the experiment was designed to test was that the aspirin
>
> 1. will purify tap water.
>
> 2. has an effect on rosebuds.
>
> 3. improves the appearance of rosebuds.
>
> 4. has the same effect on water as do rosebuds.

I contend that this item is not measuring anything that is especially scientific; instead, it is asking a question not unlike some of the items in the Watson-Glaser Test of Critical Thinking. That is, it is measuring something about the respondent's ability to handle logic and general algorithms.

This is equally apparent in the following, which appear among a list of fallacies allegedly relevant to the study of inquiry in biology:

> Assuming that events that follow others are caused by them.
>
> Drawing conclusions on the basis of nonrepresentative instances.
>
> Drawing conclusions on the basis of very small and fortuitous differences (Dreyfus & Jungwirth, 1980, pp. 310-311).

On the other side of the coin, Ross and Maynes (1983) introduce their test of experimental problem solving by acknowledging that the skills are not unique to science, although they suggest that the seven skills represent what successful scientists do. (I yearn to find out what unsuccessful ones do.) And, Arons' (1983) portrayal of scientific literacy includes being "aware of very close analogies between certain modes of thought in natural sciences and in other disciplines" (p. 93). Despite these few counterinstances, the literature of science education seems to have gathered up "scientific thinking" as if it were the exclusive property of science and so of science education.

In some respects, this is not surprising. After all, it was the natural philosophers of three centuries ago who successfully overthrew Aristotelian philosophy and its categories of theoretical sciences (physics, mathematics, and metaphysics), practical sciences (ethics and politics), and productive sciences (the arts, carpentry, medicine, agriculture, etc.). For example, early in the seventeenth century, Bacon proposed new methods *and* new categories in *Novum Organon*. But an explanation built from the history of philosophy is weak. The seemingly crystal-clear logic in Mill's *Philosophy of Scientific Method* cannot explain our enchantment with "scientific thinking" because, as Nagel (1950) reminds us in introducing the text, "the development of the statistical view of nature during the second half of the nineteenth century cast doubt on his version of what constitutes the ideal of scientific investigation" (p. xlvi). All this, of course, is aside from the development of Kantian thought up to the current "received view" of the philosophy of science, which recognizes our role in constructing reality.

Possibly, we have been misled by language. The following reminds me of this form of seduction:

> The triads that correspond in French to our English "natural sciences, social sciences, and humanities" are *les sciences naturelles*, *les sciences sociales*, *et les sciences humaines*; and in German, *die Naturwissenschaften*, *die Sozialwissenschaften*, *und die Geisteswissenschaften* (McCloskey, 1984, p. 97)

The French *science* and the German *wissenschaft* connote disciplined study. In English, as McCloskey points out, it means this and much more: experimental work, quantification, etc., all of which suggest that science is very different from, say, history, or the explication of text, which is literary criticism. The English language appears to deny that such scholarly pursuits involve disciplined study.

How we got to the point of believing that "scientific thinking" belongs in science education is far less important than facing the arrogance of this view.

ARGUMENT TWO: THE QUESTION OF HOW WE THINK

I am not going to describe how we think; but I am going to argue that whatever "scientific thinking" is, *it* doesn't describe how we think either. I do not want to touch the question of how scientists think, because I believe that the literature in philosophy of science has shown adequately that "scientific thinking" is not a plausible candidate. Instead, I want to find out what "scientific thinking" might be. The journey to the answer is short.

Somewhat buried in the literature is a fine paper by Daniels (1975), "What is the Language of the Practical?" In this, the author attempts to uncover the ways in which psychological processes (as in "the cognitive process approach") are different from physical processes. I see this work as relevant because much of the language of "scientific thinking" corresponds to cognitive process language. Daniels argues:

> Our talk about mental processes has a logic very different from the logic of our talk about physical processes. Physical processes can be observed and identified independently of any product they may have; mental processes can be identified only via their products. At least in principle, a physical process, such as baking or synapse-firing can be identified as a process independently of what it produces. Of course, in some cases, it is extremely difficult, even physically impossible, to observe an ongoing process. But with mental processes we are not faced with difficulty or physical impossibility; we are faced with something more like logical impossibility. This is true, at least, of mental processes in people other than ourselves. (p. 249)

As Daniels explains, we identify psychological processes by their products. So, when an inference appears, we suppose that something has been happening mentally. Then comes the awkward part. Because it is important for us to talk about these processes, we have to secure them in language by naming them. But they are not ostensible. "Showing and telling" won't work. So we invoke a rather elaborate ex post facto system and name the process after the word that describes the product. In this way, the process yielding an inference is "inferring," that yielding a comparison is "comparing," that giving a definition is "defining," and that resulting in an hypothesis is "hypothesizing." This language trick is enormously deceptive. I think we have been misled into thinking that because we can name these processes, they exist; and, we have come to think of them as existing as separate, identifiable processes that are thus capable of being isolated and developed by teaching.

What we have to recognize is that psychological processes and their counterparts in "scientific thinking" have meaning only because we can talk about them. This is precisely what Dewey was driving at when he wrote beneath "Logical Forms not Used in Actual Thinking, But to Set Forth Results of Thinking":

> In short, these forms apply not to reaching conclusions, not to arriving at beliefs and knowledge, but to the most effective way in which to set forth what has already been concluded, so as to convince others (or oneself if one wishes to call to mind its grounds) of the soundness of the result. In the thinking by which a conclusion is actually reached, observations are made that turn out to be aside from the point; false clues are followed; fruitless suggestions are entertained; superfluous moves are made. (Archambault, 1964, p. 245)

The impact of Argument Two is as follows: Although we may attempt to focus instruction upon "scientific thinking," we can never in principle know that we are having any impact at all on the development of the psychological processes we believe should occur. This will always be true, even though we may use instruments to measure the products of this thinking. This is because the notion of "scientific thinking" cannot be known to bear any relationship to how we think.

ARGUMENT THREE: "SCIENTIFIC THINKING" THRIVES

Argument Three is not a very substantial one, but it is important to show that "scientific thinking" is not a straw man, developed out of nothing in order to serve as this author's target. What is provided below shows that the notion of "scientific thinking" lives in the literature of science education and its research endeavors. (There is no attempt to cover the territory completely or to sample it scientifically.)

The "Test of Experimental Problem Solving," developed by Ross and Maynes (1983), is closely related to "scientific thinking" and is a recent arrival on the scene. Interestingly, it appears in the same issue of the Journal of Research in Science Teaching as a paper by Finley (1983) that shows the conceptual relationship of "science processes" to empiricism, and then argues that logical empiricism represents a fundamentally inadequate account of the nature of science! The "Test of Enquiry Skills" has been developed by Fraser (1980). Tobin and Capie (1982) have developed a group test of integrated science processes. A large number of earlier devices exist, as Mayer's (1974) review attests. Not only are the tests of these various versions of "scientific thinking" available, the research literature itself reports many examples of their use. Indeed, the area has now reached the point where its many studies have been subjected to meta-analysis (Steinkamp & Maehr, 1983).

Clearly, the idea of "scientific thinking" is alive and well, but it is not without its detractors. Kyle (1980) contends:

> The time has come for science educators to limit the use of the term "scientific inquiry" to that which constitutes scientific inquiry from the scientist's point of view. By placing proper constraints on what constitutes scientific inquiry, the many other descriptors of science education will be able to reflect more accurately what is really happening in the science classroom and laboratory. (p. 128)

"Scientific thinking" is promoted in some so-called methods texts for beginning science teachers. For example, Trowbridge, Bybee and Sund (1981) present a very orthodox empiricist view in a section that distinguishes between discovery and inquiry strategies (p. 168), even though an earlier chapter attempts to give equal consideration to "deductive," "inductive," and "conjecture and refutation" models of the nature of science. Simpson and Anderson (1981) open their text with an account of scientific literacy that, among other things, involves the use of "the processes of science in solving problems, making decisions" and includes understanding the nature of science (p. 6). Similarly, Collette and Chiapetta (1984) present a clear account of "scientific thinking" in their first chapter. Here, six clear steps are presented, with the caution that "research scientists do not necessarily follow this step by step procedure nor do they follow any absolute number of steps to solve problems" (p. 8).

There follows an account of science that leaves this reader with the thought that scholars in other disciplines do not generate hypotheses, nor test hypotheses against data. This chapter's summary is also misleading:

> Science is also a way of thinking. Approaches to obtaining information have changed greatly through the centuries, from the tight logic and deductive procedures to empiricism and inductive procedures, and from the search for nature's laws in the past century to the search for statistical probabilities in this century (p. 23).

(The terms "statistics" and "probability" do not appear in the text's index or table of contents.) Later still, the reader is informed that observing, classifying, inferring, predicting, hypothesizing, and interpreting are among the thirteen "thinking processes that are associated with science" (p. 71). These few examples show that the idea of "scientific thinking" is present in methods texts and even emerges in rather confused ways.

CONCEPTUAL ANALYSIS AND CRITICAL REFLECTION

I have argued that the notion of "scientific thinking" and what it subsumes is problematical. That is, it is not straightforwardly the case that "scientific thinking" is central to science and to science education, nor that the concept speaks adequately to how a scientist or anyone else thinks. These are the grounds for finding that the concept of "scientific thinking" is problematical, and because the concept is used in science education, it is a problematical educational concept too.

The realization that an educational concept is problematical has important consequences for teacher preparation. If the intent of professional preparation is to equip students with the means to be able to act with thoughtful autonomy, then it has to follow that programs must present the problems of the field and not pass these over. If the problems are not addressed, the opportunity for students to be autonomous is necessarily truncated. As Hawkins (1983) observed of teaching in a different setting, the danger is that "they might uncritically accept the errors that adults so often uncritically impose" (p. 73).

Professional autonomy is linked to a critical reflection upon professional practice. And, for pre-service science teachers to begin to reflect critically, they must learn to interpret all that they read, see, and hear, both in college courses and in practice-teaching experiences. This is true of the curriculum materials such students read and use, just as it is true of the research that they encounter.

It is one thing to use research results in teacher education programs; it is quite another to make it possible for pre-service teachers to learn how to make critical assessments of that research. Yet, if pre-service education is to meet the goal of fostering autonomy, then its graduates must be able to reflect critically upon research that they might encounter during their professional years. Such reflection requires a minimal understanding of research techniques, but that is not all. Critical reflection also involves raising questions about the conceptual basis of the research, and this suggests that teacher education programs need to include opportunities for pre-service candidates to consider the results of alternative research, especially research that is critical of standard and fundamental conceptualizations.

Conceptual analysis, as used in Argument One and in other places (for example, Munby & Russell, 1983) is a powerful technique for revealing the assumptions underlying the central concepts of an area. This chapter illustrates the dangers of an uncritical acceptance of the meaning of "scientific thinking," and proposes that conceptual analysis is a significant part of any curriculum that intends to develop the critical reflection of science teachers.

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